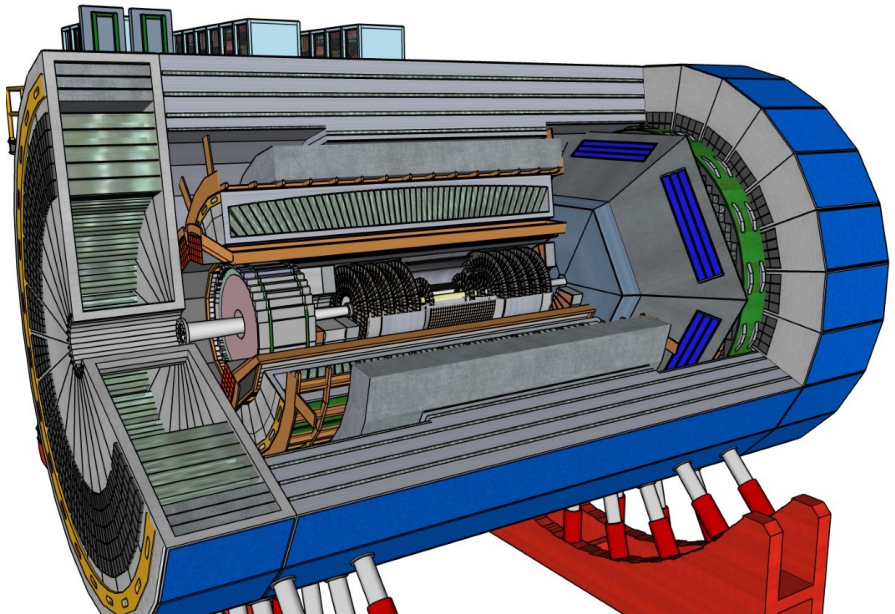
EIC Comprehensive Chromodynamics Experiment

Or Hen, Tanja Horn, John Lajoie

for the ECCE Consortium

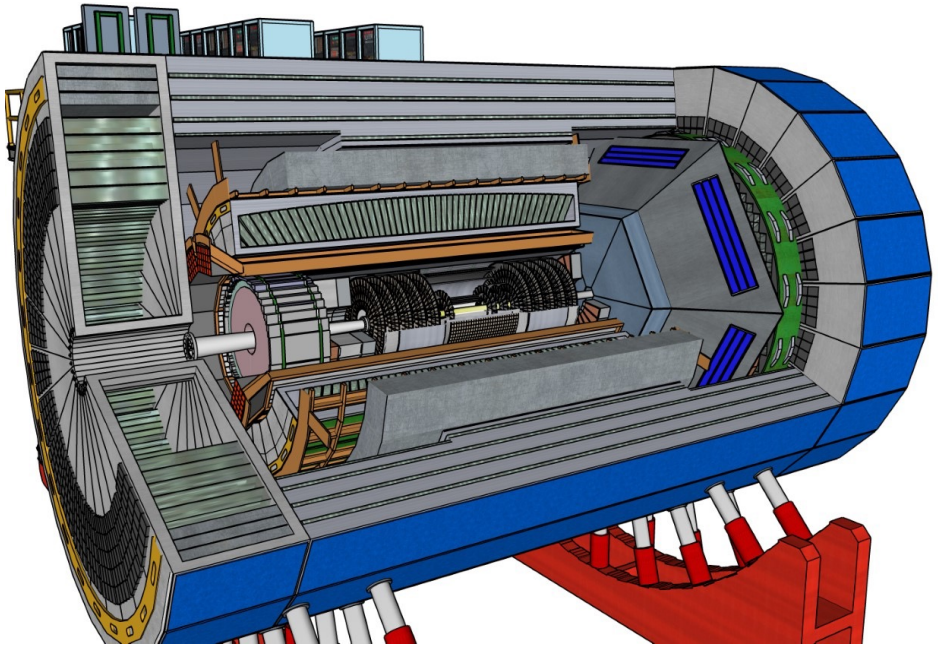


EIC Users Group Summer Meeting, August 3rd, 2021.

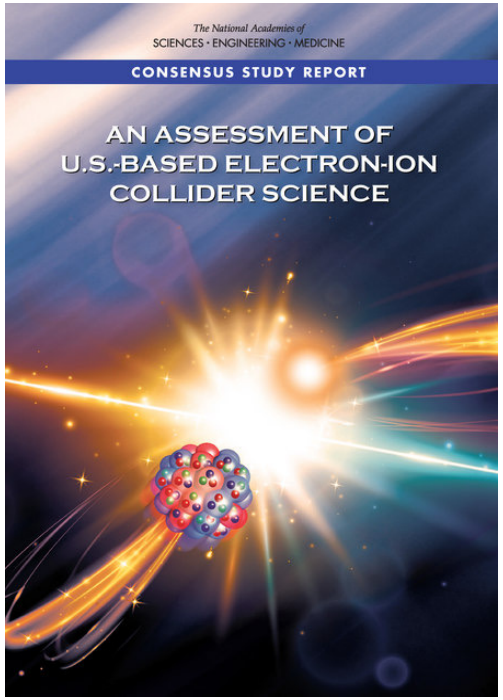
What's ECCE?

Scientist from 80 institutions

Designing (& building!) a detector



To deliver on EIC science mission



What's ECCE?

ECCE is developing a low-risk, cost-effective, flexible and optimized EIC detector, capable of delivering on the full EIC physics program*!

*EIC physics program? As defined by the U.S. National Academy of Science Study & EIC White Paper

What's ECCE?

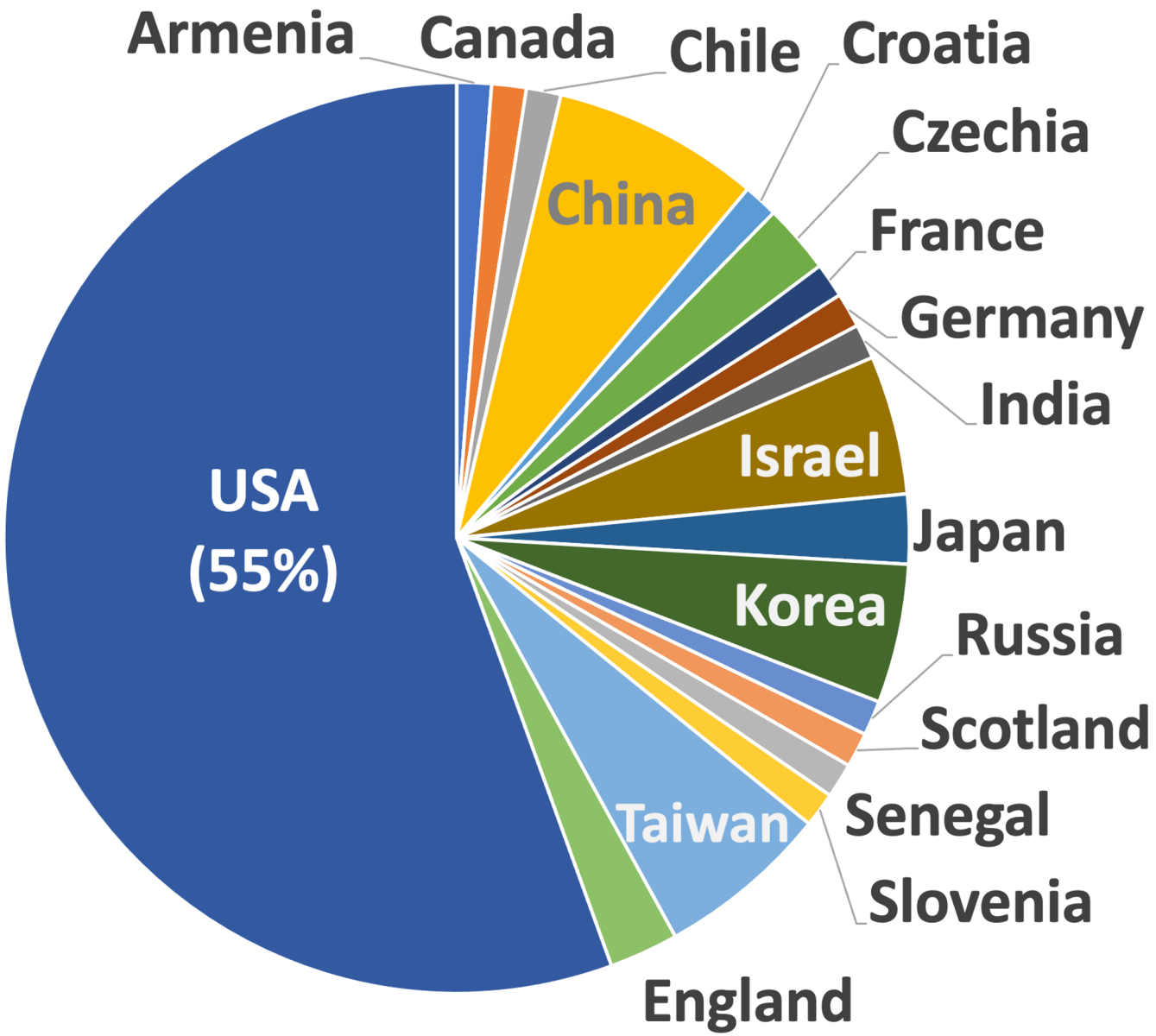
ECCE is developing a low-risk, cost-effective, flexible and optimized EIC detector, capable of delivering on the full EIC physics program!

Guiding principles:

- Reuse: 1.5T BaBar solenoid / detectors / infrastructure (as much as possible)
- Explore both EIC interaction regions (i.e. with/out secondary focusing)
- Respond to 'Detector 1' EIC call for proposals (i.e. ready for CD4a)
- Share & support community vision that the EIC science mission is best served by two detectors

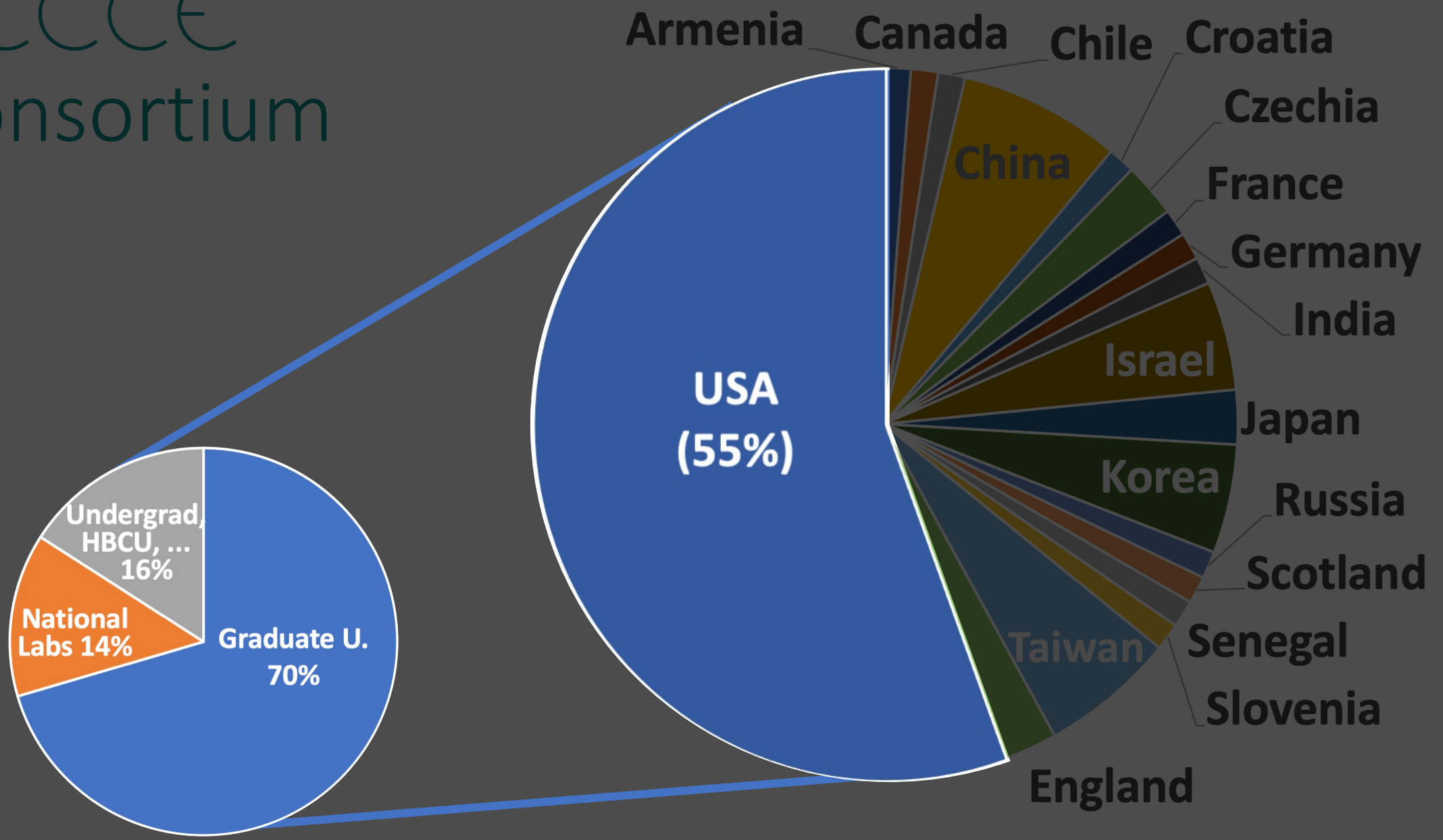
ECCE Consortium

[80 Institutions]



ECCE Consortium

[80 Institutions]



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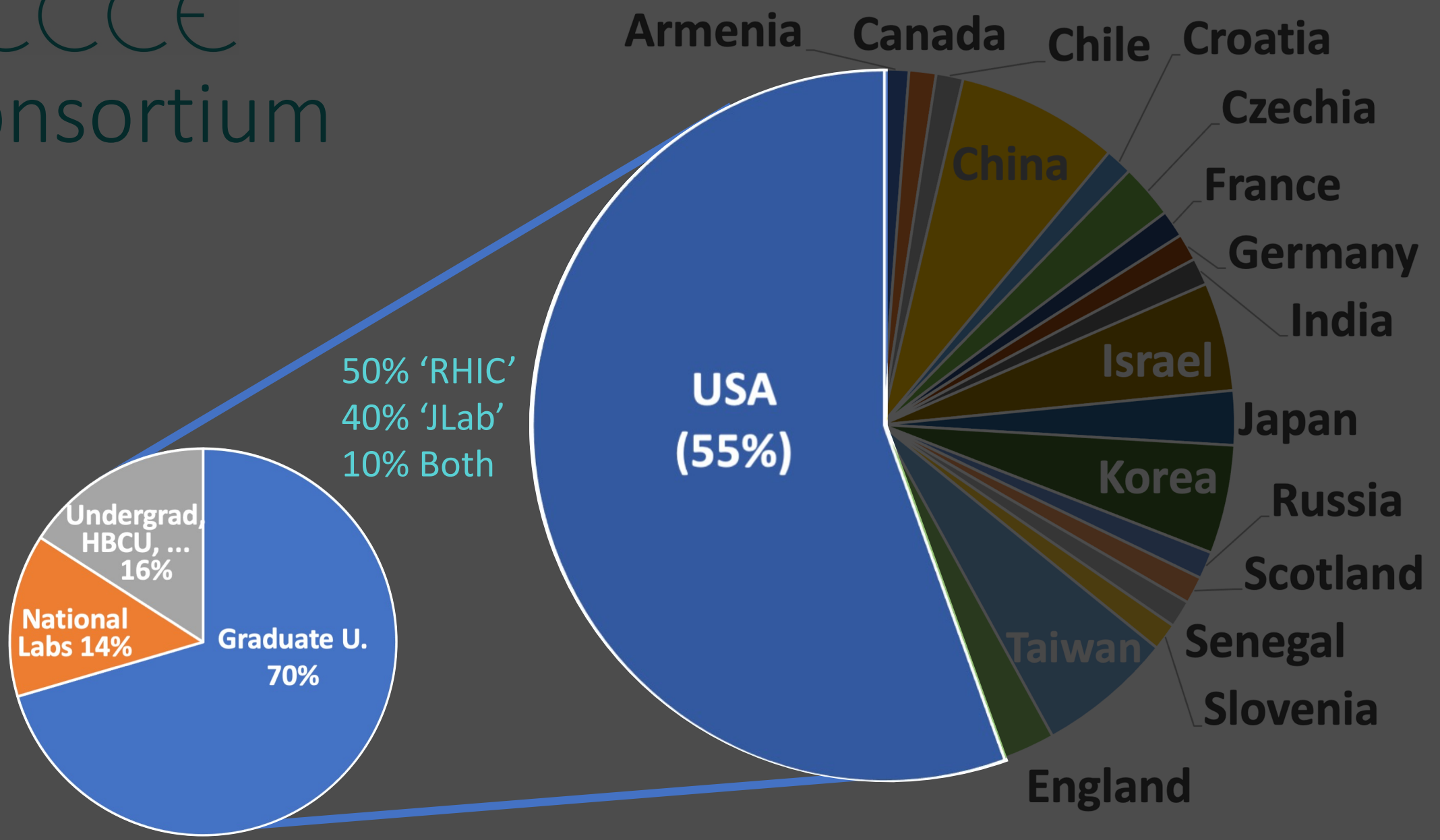
[80 Institutions]



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David Lawrence (JLab)

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  Joe Osborn (ORNL)

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- Far Forward/Far Backward*
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- Tracking
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- Calorimetry
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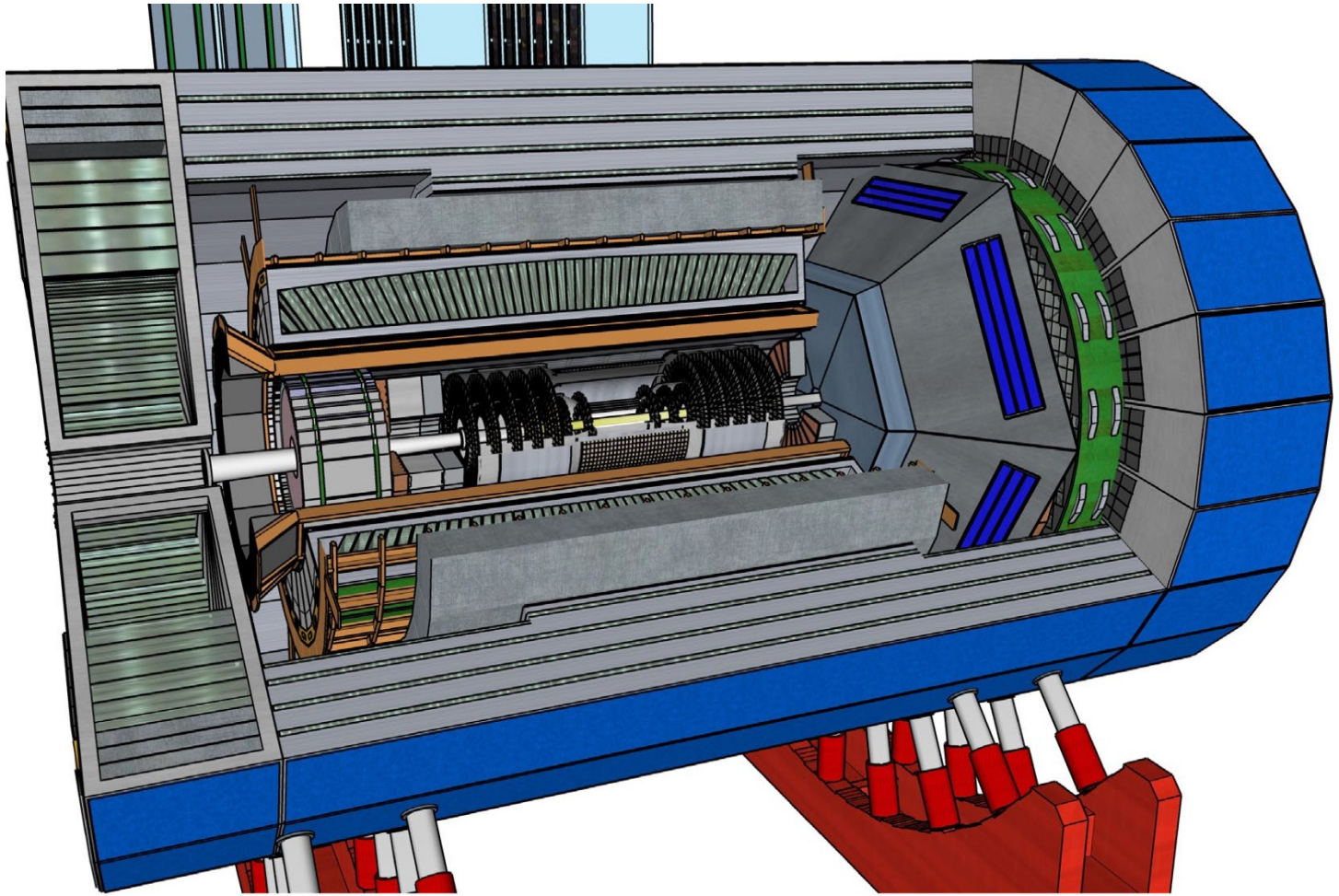
ECCE Detector Layout



ELECTRON ENDCAP

Tracking: Si discs + Large area μRWELL
Electron Detection:
- Inner: PbWO4 crystals (reuse some)
- Outer: SciGlass (backup PbGl)

h-PID: mRICH & AC-LGAD
HCAL: Fe/Sc (STAR re-use)

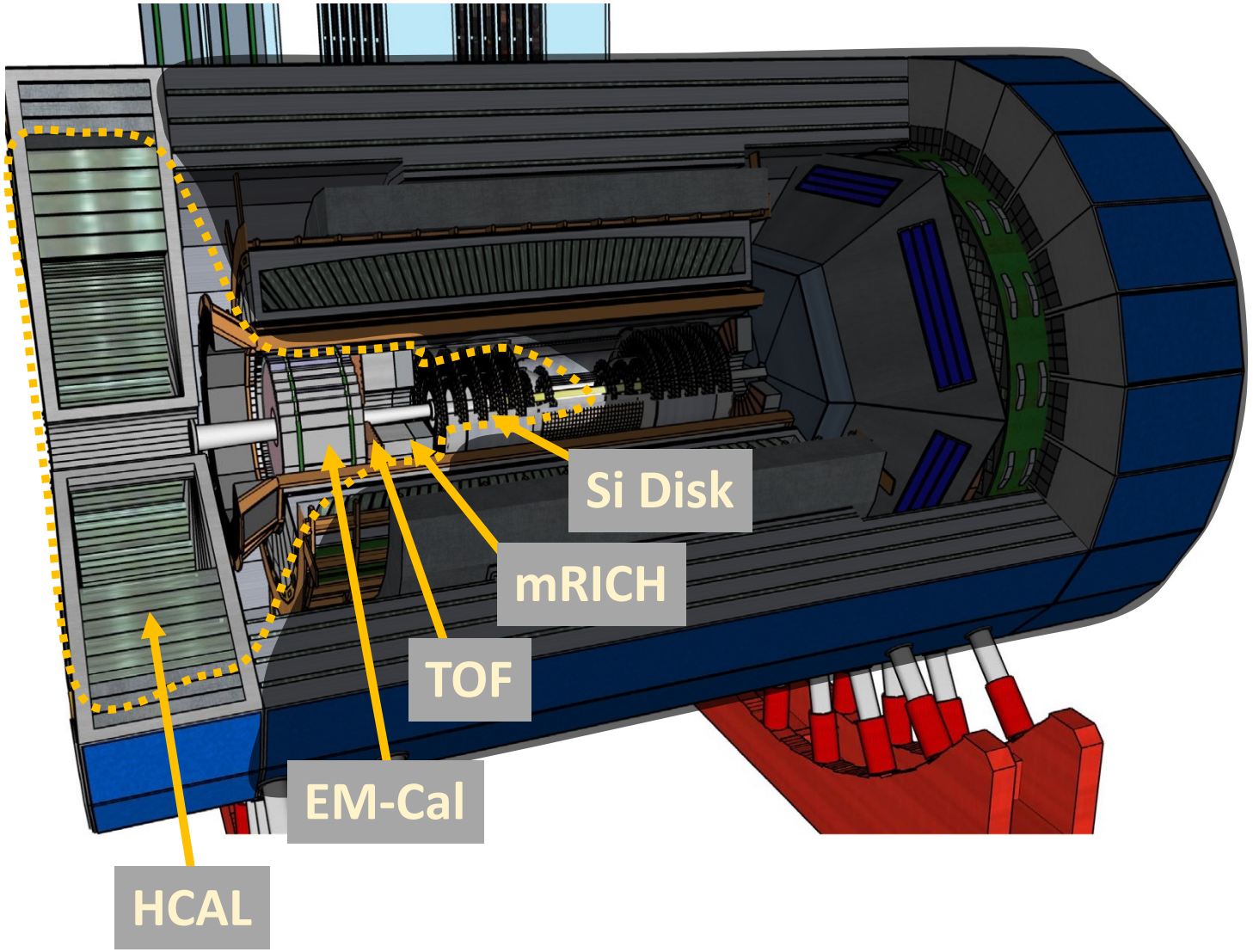
CENTRAL BARREL

Tracking: MAPS Si + μRWELL
(design under optimization)
Electron PID: SciGlass (alt: PbGl or W(Pb)/Sc shashlik)
(plus instrumented frame)
h-PID: hpDIRC & AC-LGAD
HCAL: Fe/Sc (sPHENIX re-use)

HADRON ENDCAP

Tracking: Si discs + Large area μRWELL
PID: dual-RICH & AC-LGAD
Calorimetry:
Standard Pb/ScFi shashlik (PHENIX re-use)
Long. sep. HCAL
(other options under study)

ECCE Detector Layout



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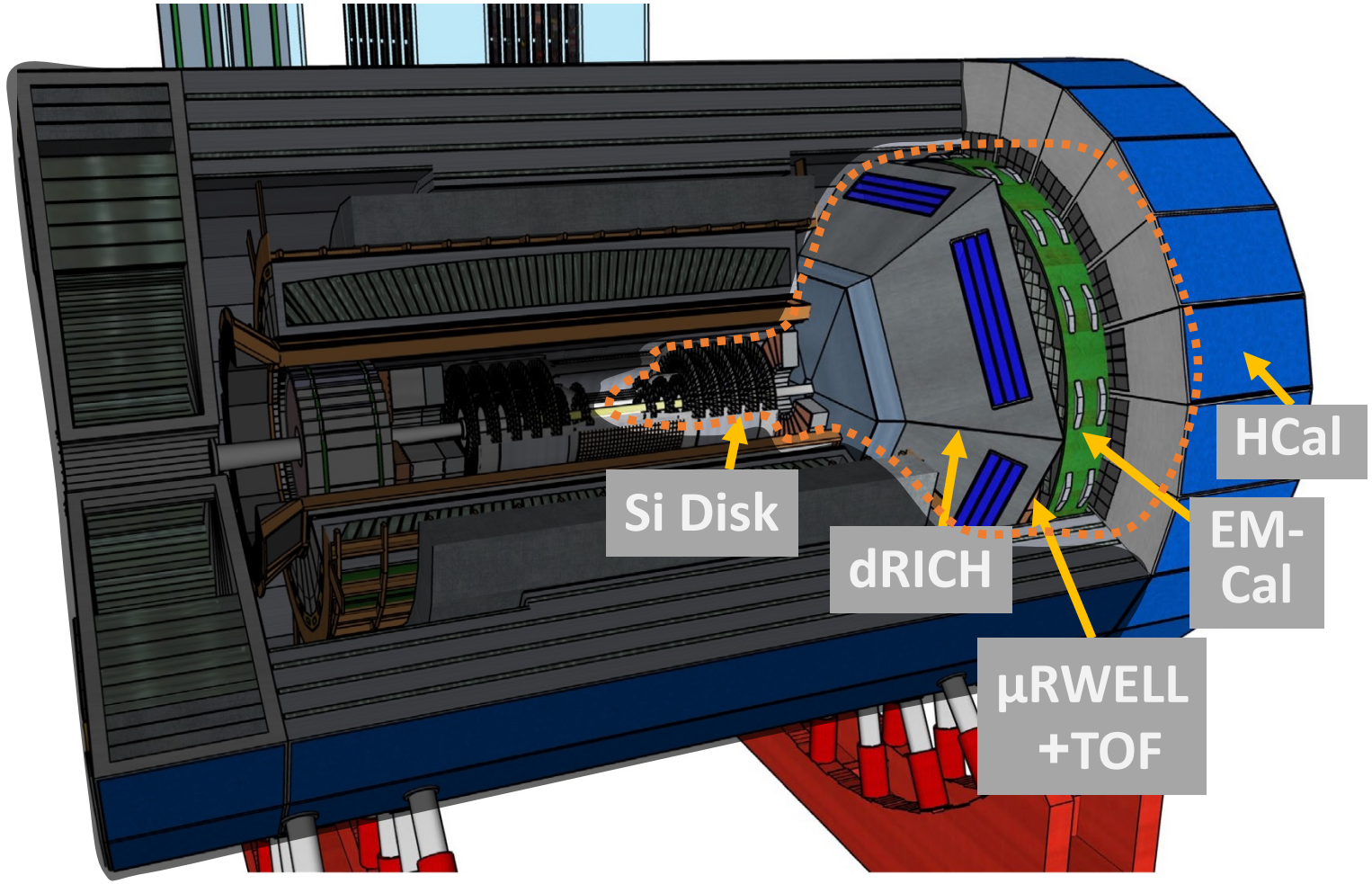

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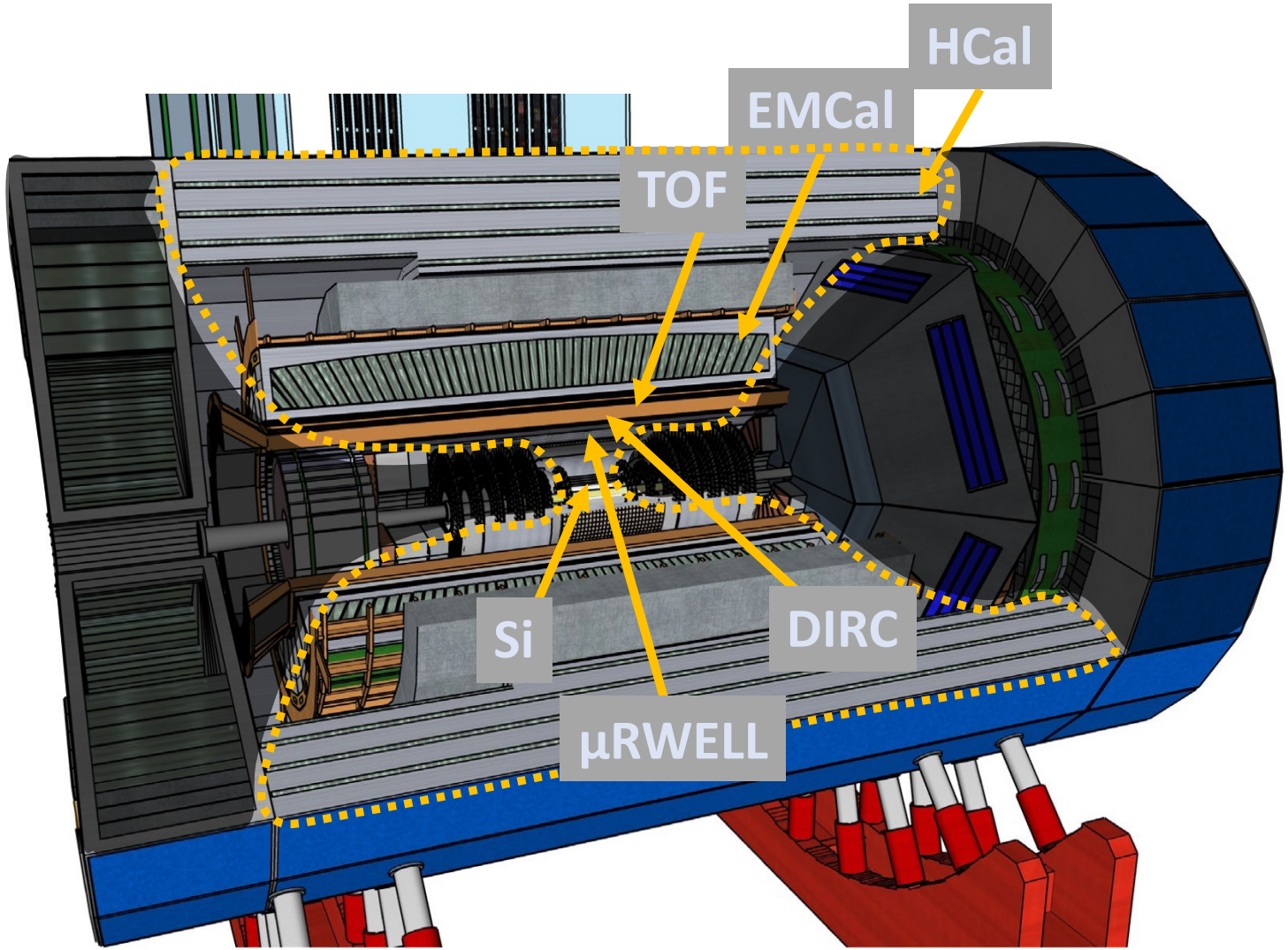

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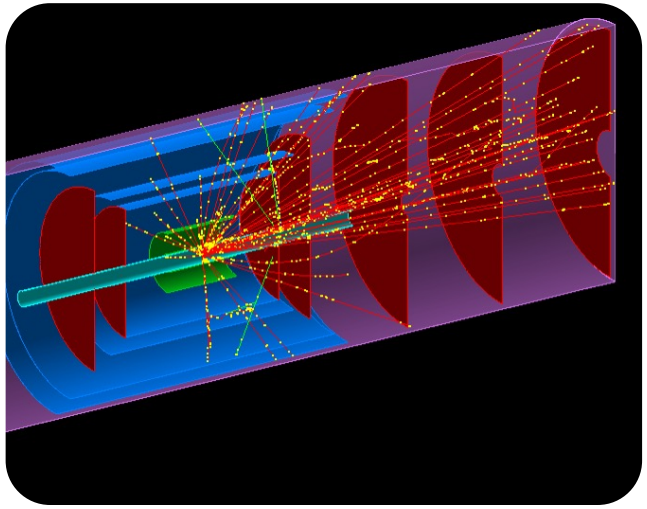
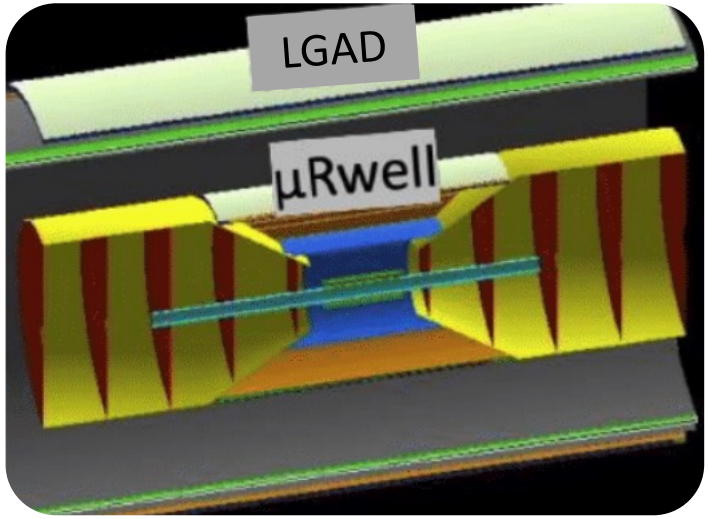
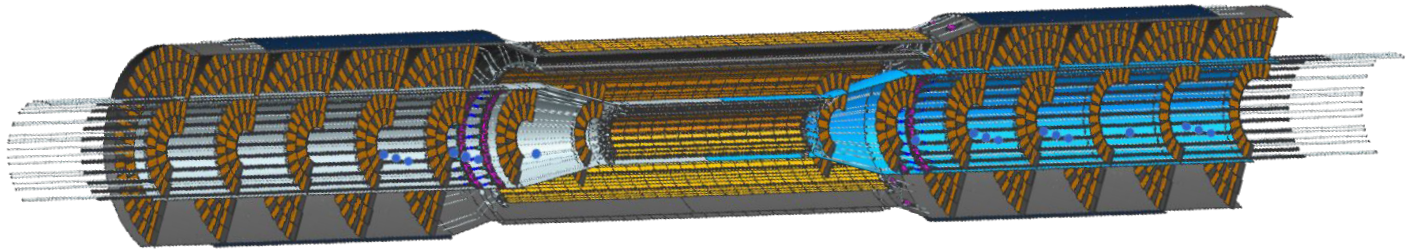
(plus instrumented frame)
h-PID: hpDIRC & AC-LGAD
HCAL: Fe/Sc (sPHENIX re-use)

ECCE Tracking

- Baseline Layout:
  - Barrel: Silicon tracker (2 double layers) + AC-LGADS & µRWELL around DIRC
  - Endcaps: Silicon disks + AC-LGADS & µRWell around calorimeters
- AI/ML pipeline for optimizing tracker design

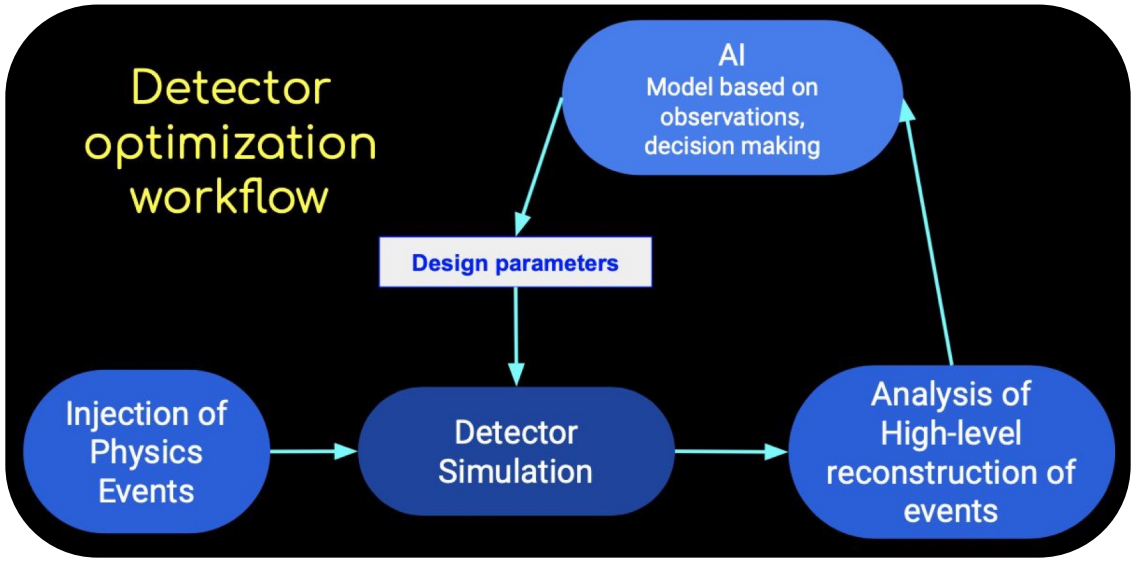


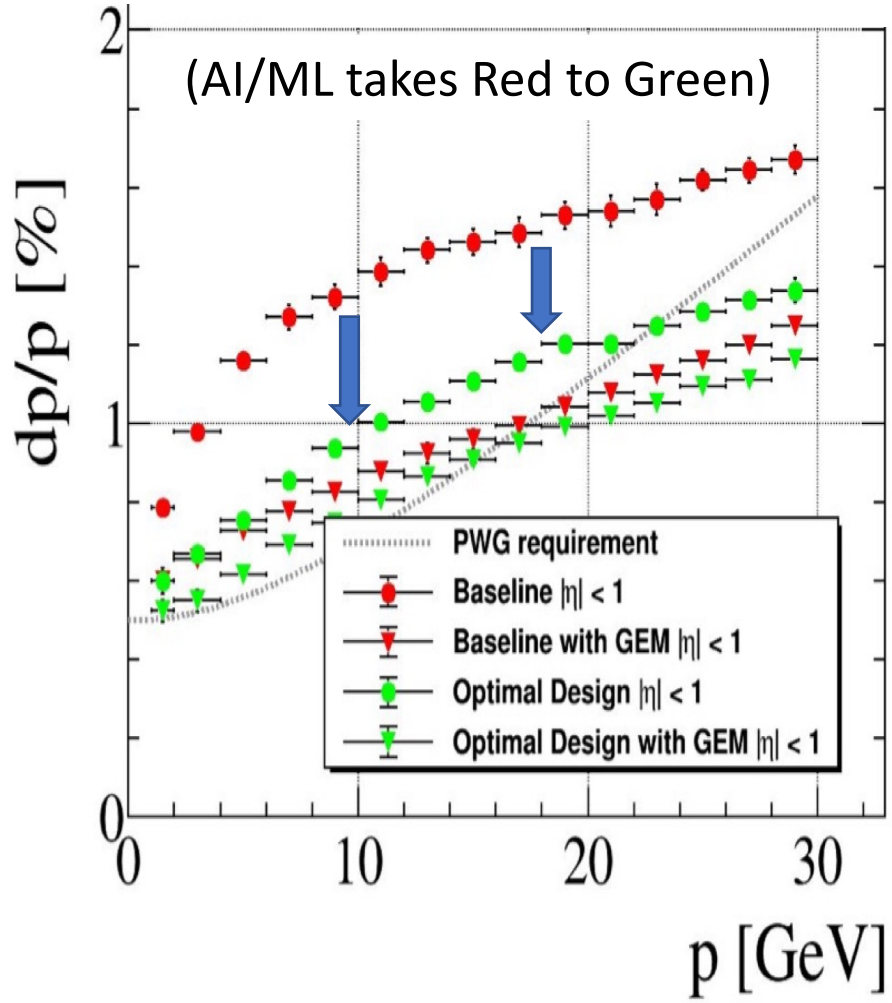




ECCE Tracking + AI

Multidimensional tradeoff optimization for multiple criteria (momentum, angle & pointing res., reconstruction efficiency, ...)

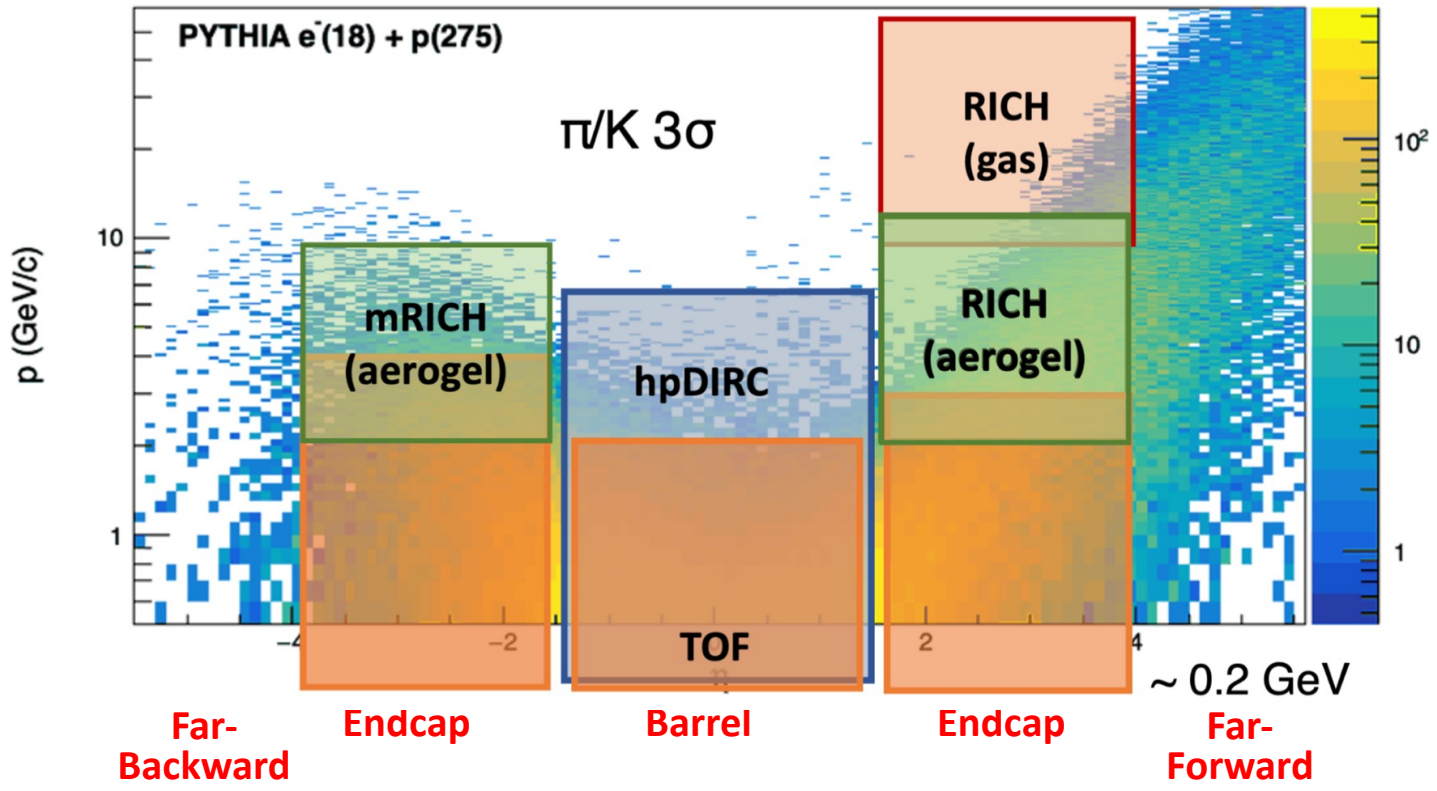




ECCE PID

- Largely based on YR studies
- Combination of Cerenkov, Calorimetry & TOF
- Full G4 Implementation
  - ⇒ Performance studies underway
  - ⇒ Optimizing TOF

(AI/ML optimization here as well!)



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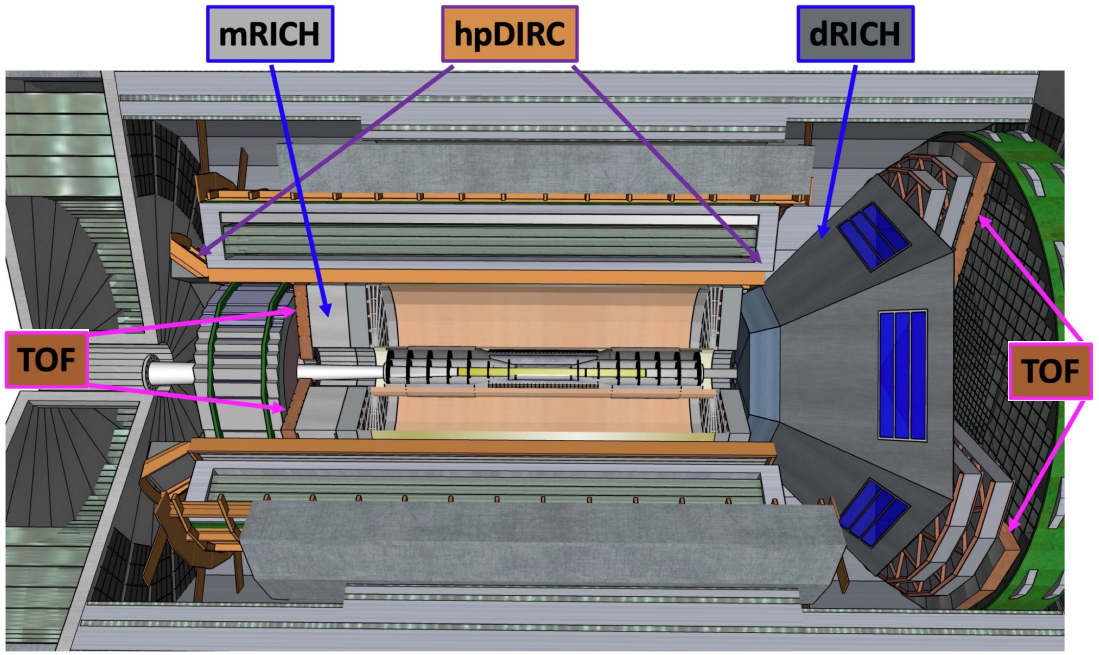
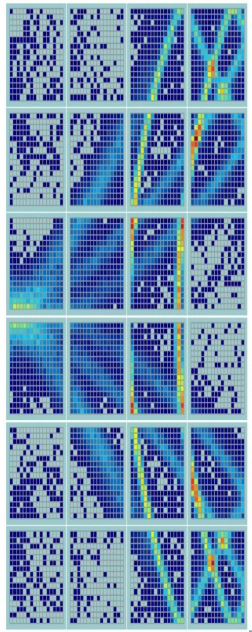
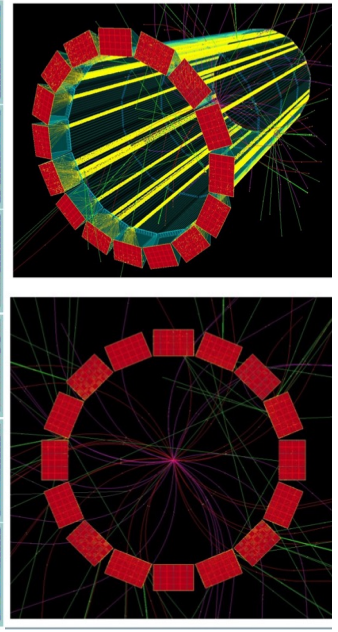
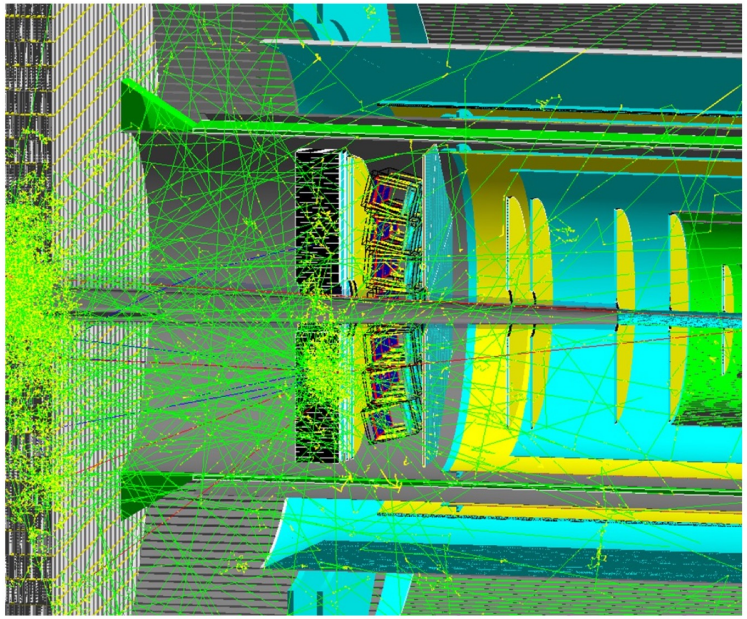








ECCE Calorimetry

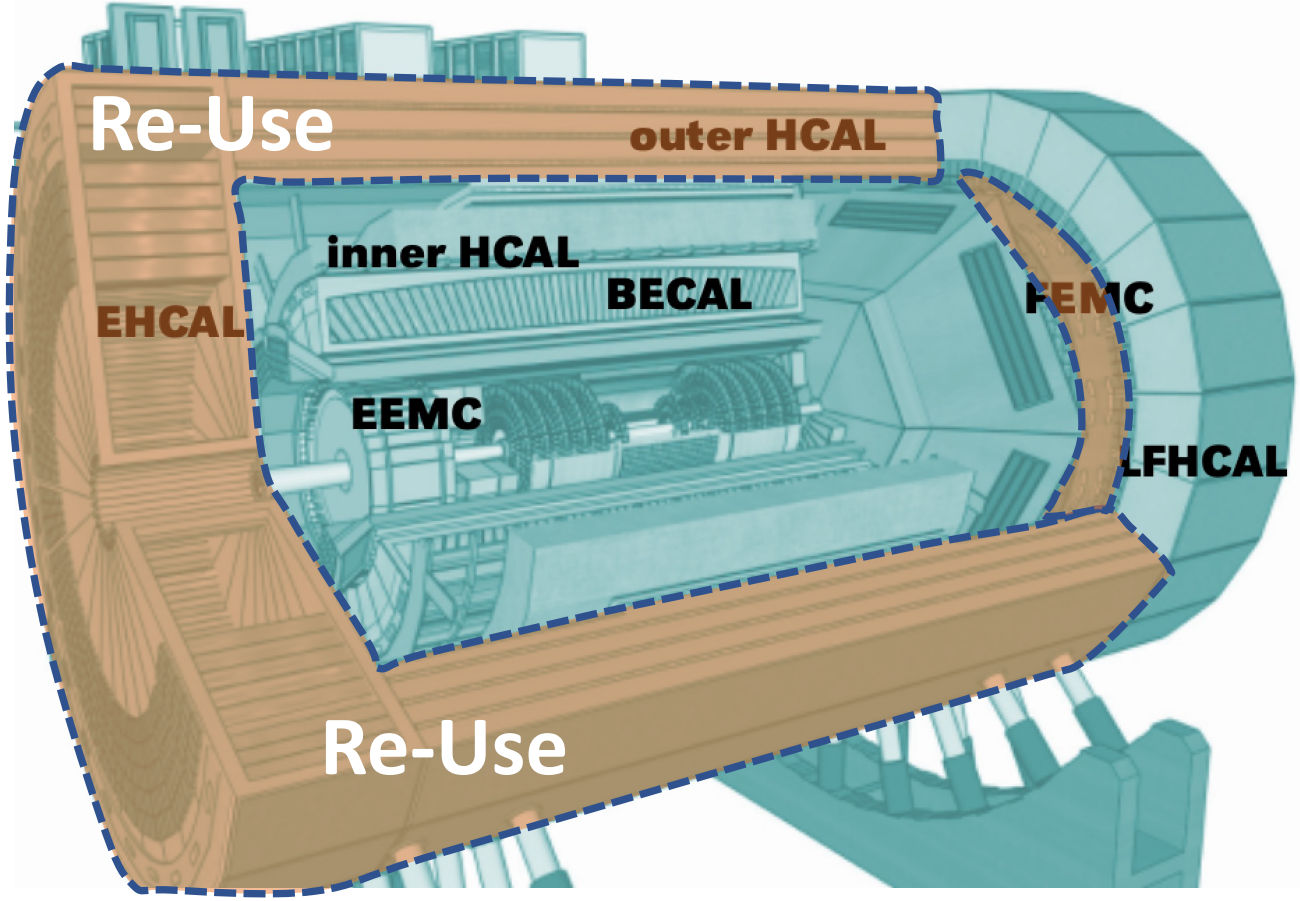
Re-use:

- STAR forward & sPHENIX outer HCal
- Re-use PHENIX Shalik EMCal (\w upgraded readout)

New:

- Homogenous EMCal (SciGlass)
- Inner Hcal (barrel EMCal support frame)
- Backward EMCal (PbWO4 + SciGlass)
- Longitudinally separated forward HCal

  [Alt / upgrade: forward DREAM Cal]



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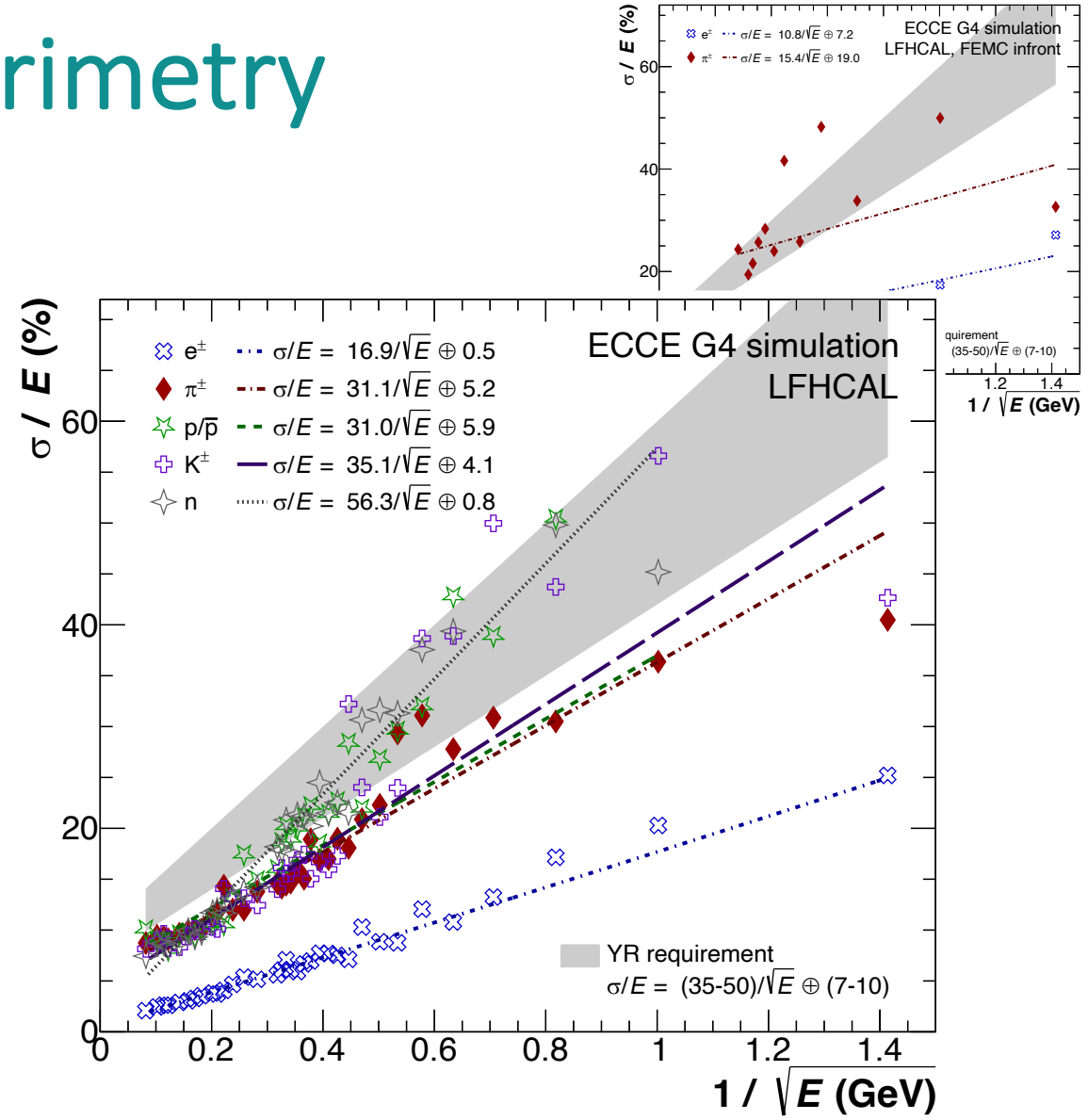
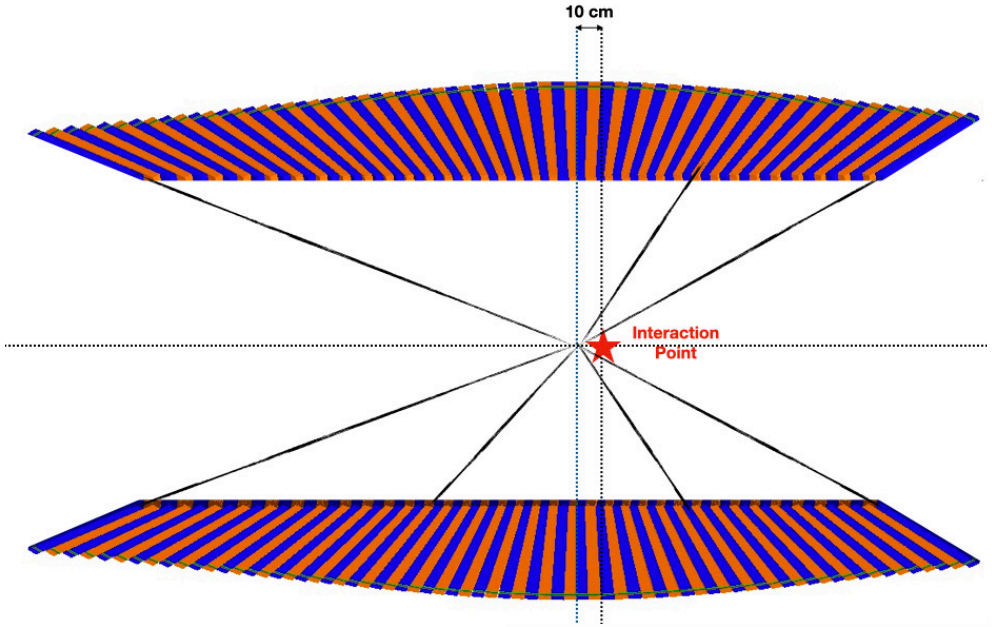
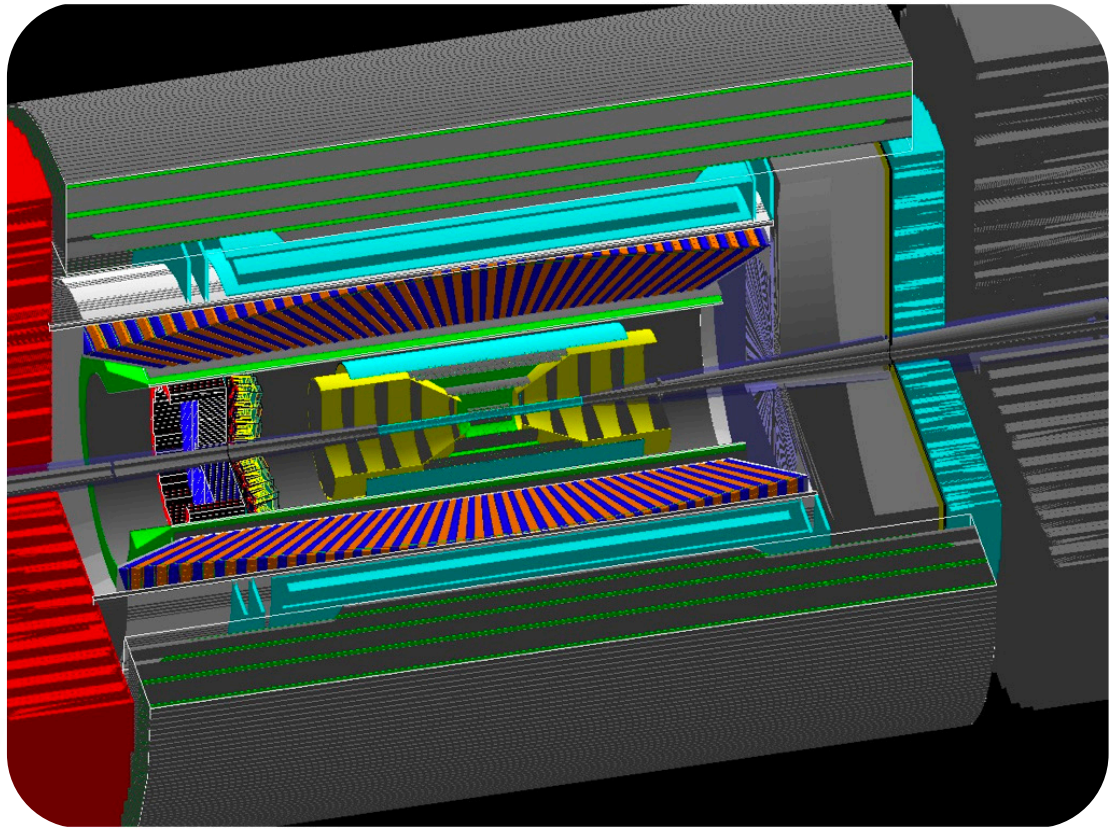
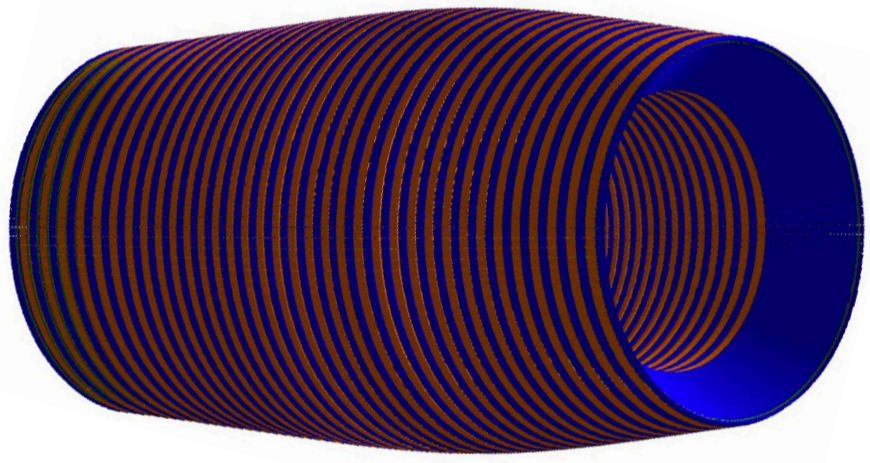


ECCE Calorimetry

Projective EM-Cal already implemented: ☺







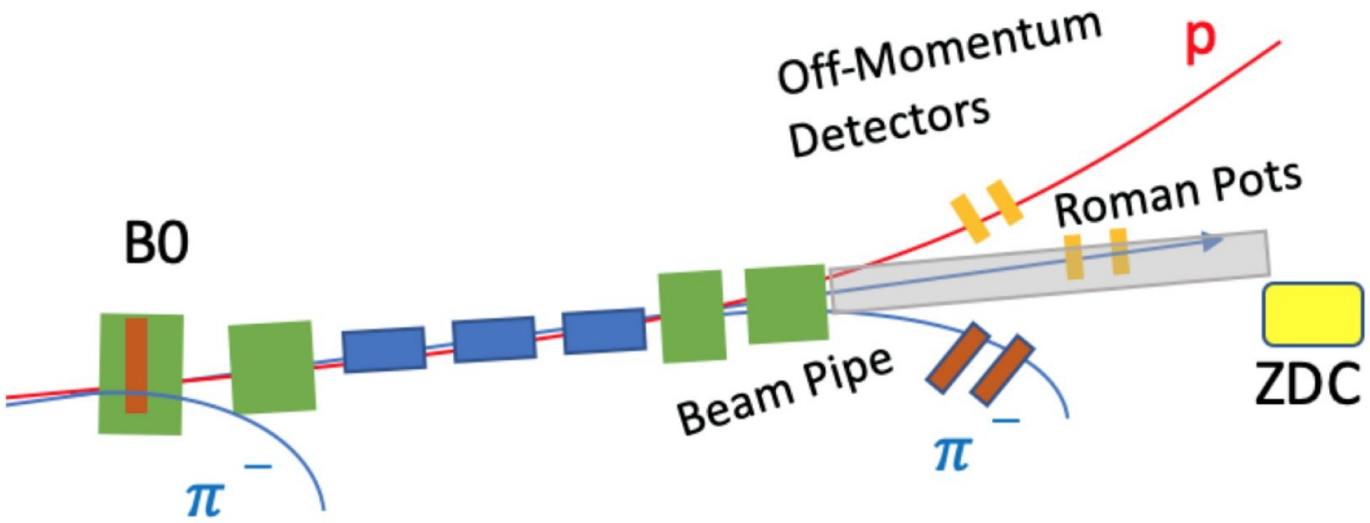
*Nathaly Santiesteban + Calorimetry WG

ECCE Far Forward / Back

FAR FORWARD DETECTORS

- ZDC – **Si/W & PWO (SciGlass)**
- Roman Pots – **Silicon sensors, AC-LGADs**
- Off-momentum det. – **Silicon sensors**
- B0-trackers – **MAPS & timing layers**

Lepton polarimetry
hadron polarimetry



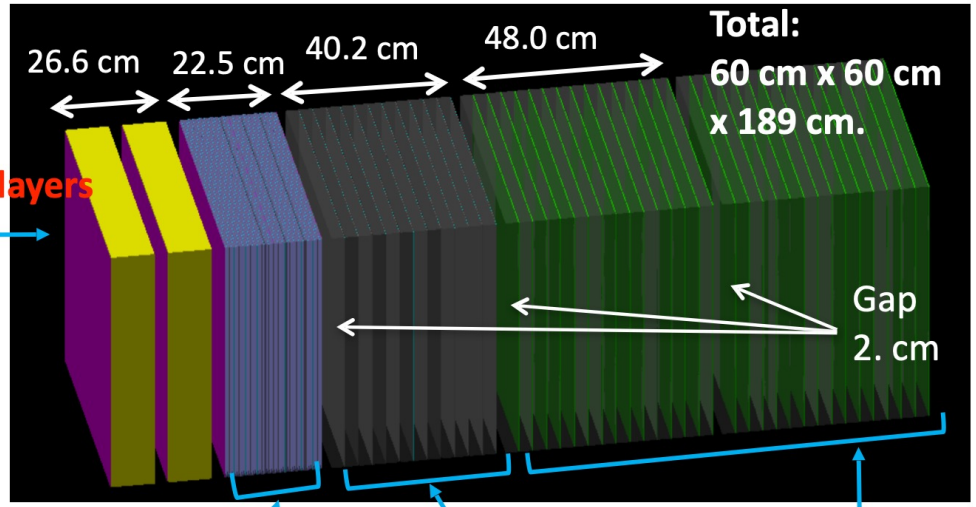
FAR BACKWARD DETECTORS

- low-Q2 tagger
- Lumi-detector

Lepton polarimetry
hadron polarimetry

Participating in coordinated meetings between all proto-collaborations, organized by EIC PM.

ZDC Example



Silicon
3 mm x 3mm x 300 µm
PET (Glue) 0.11 mm
PET (FPC) 0.28 mm
Gap 1.2mm
Crystal (PbWO4)
3cm x 3cm x 10 cm
Gap 3 cm

2 layers

Si +

12 layers

30 layers
(15 layers x 2)

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue) 0.13 mm
PET (FPC) 0.28 mm
Gap 1. mm

5.34 mm

Pb 3cm Thickness
PET (Glue) 0.11 mm
Silicon 1 cm x 1 cm x 320 µm
PET (Glue) 0.13 mm
PET(FPC) 0.28 mm
Gap 1. mm

x 2

20 layers

+

1 layer

Tungsten 3.5 mm Thickness
PET (Glue) 0.11 mm
Silicon 3 mm x 3mm x 300 µm
PET (Glue) 0.11 mm
PET(FPC) 0.28 mm
Gap 1.2mm

5.5 mm

Total:
W: 42 layers,
Si: 3 layers,
Si: 40 layers

Pb 3cm Thickness
Scintilator 10 cm x 10 cm x 2 mm
Gap 0.0013 mm

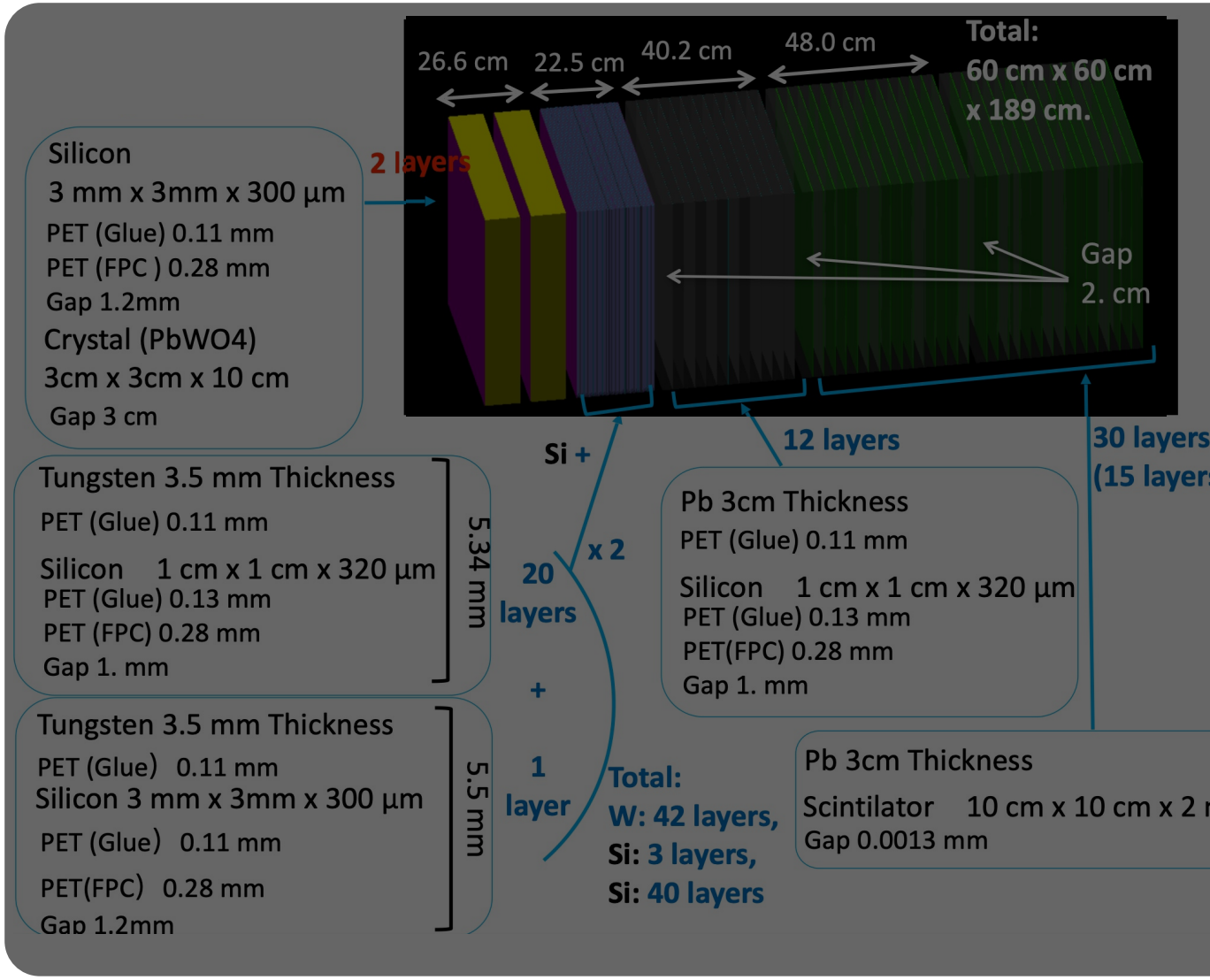
ZDC Example

Optimizing for:

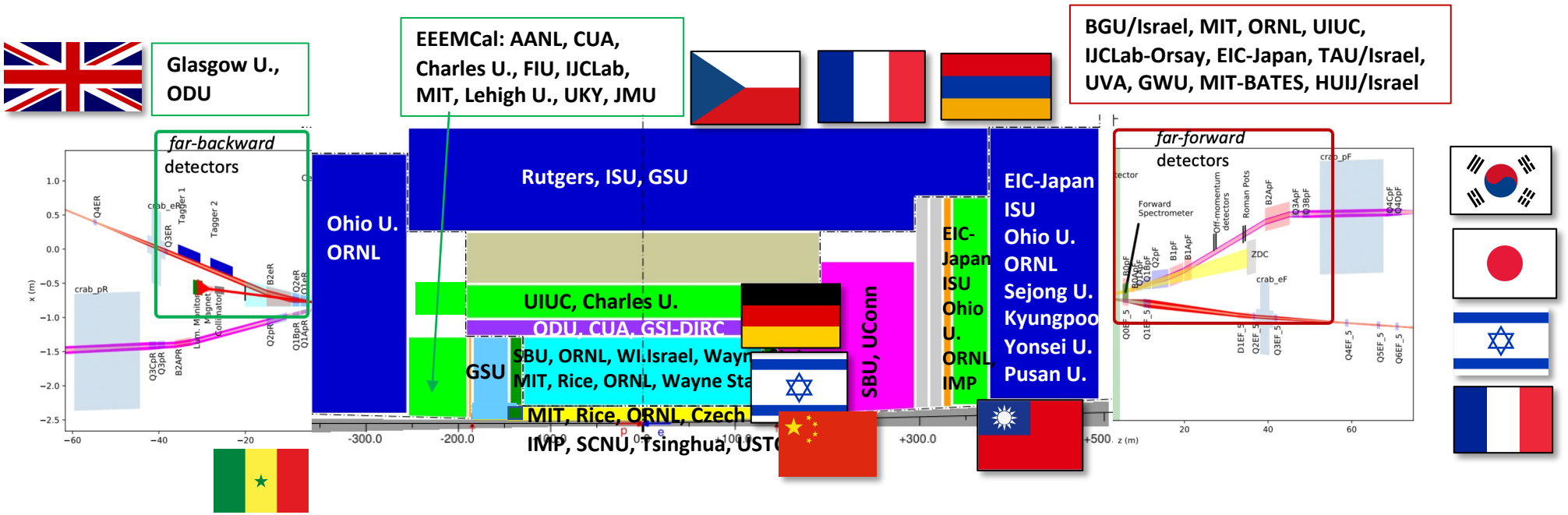
- Neutron / photon separation
- Energy reconstruction
- Position resolution

Recent improvements:

- Reduced Crystal size
  (10x2 cm^2 → 7x2 cm^2)
- Reduced layers (W/Si, 42 → 30)
- Adding charged particle veto



ECCE International Interests



Polarized Beam and polarimetry: MIT, UNH, SBU

Electronics: Columbia, ORNL

DAQ/Trigger: ISU, CU Boulder, OU, ORNL, SBU, UConn, LLNL

Artificial Intelligence: MIT, CNU, Brunel U.

CENTRAL

Tracking:

- Silicon: China, Czech Republic, Japan

Calorimetry

- PWO and SciGlass: Czech Republic, Armenia, France
- Forward Calo/Dual Readout: China, Japan, South Korea

Particle ID

- DIRC: GSI/Germany

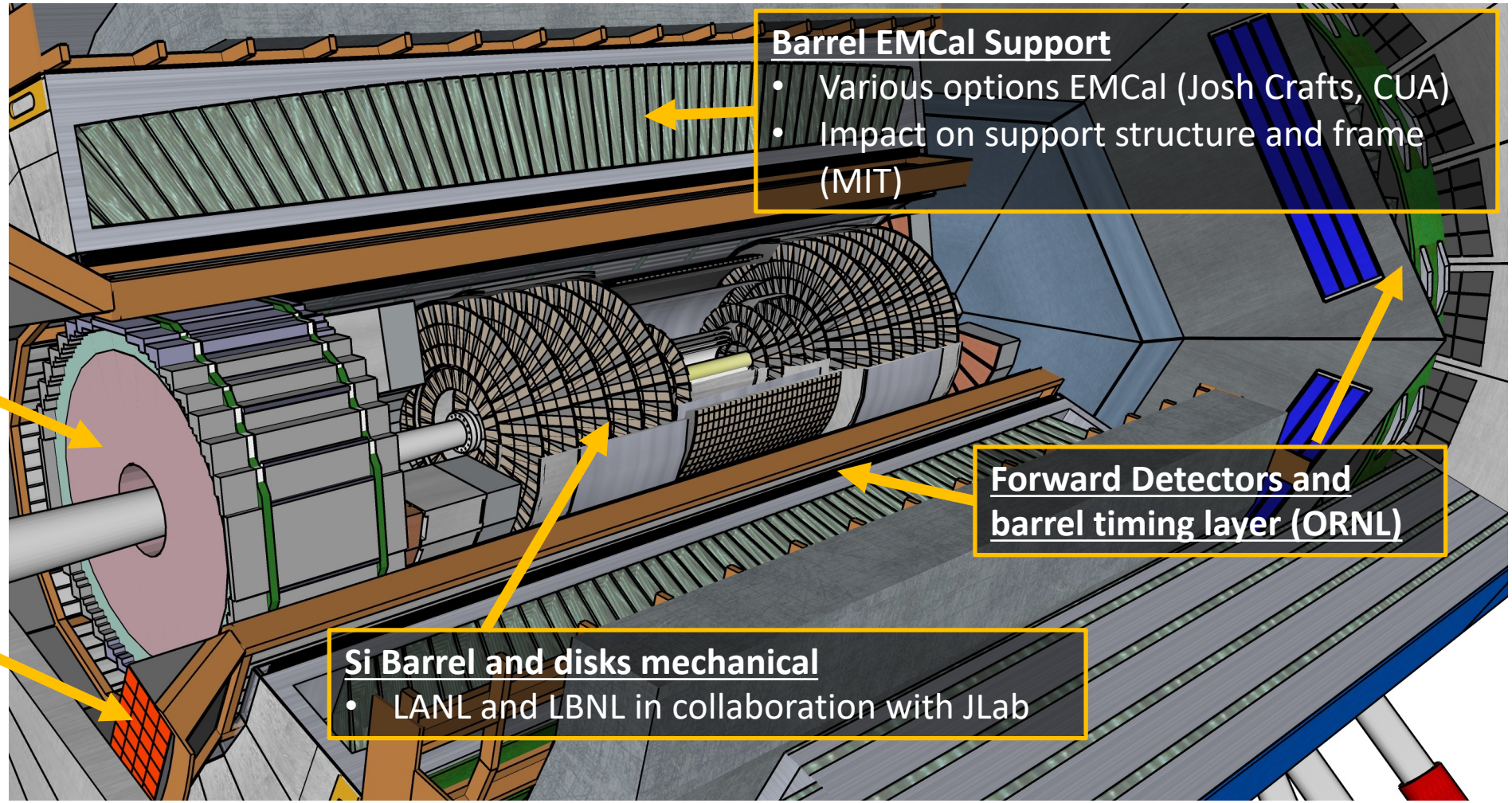
FAR FORWARD – FAR BACKWARD

- Roman pots: France
- Off momentum: Israel
- ZDC: Japan
- Luminosity monitors: Israel
- Low Q2 tagger: UK

ECCE Mechanical Integration

Electron Endcap EMCal
- Initial concept (Josh Crafts, CUA)
- Frame & cooling system (IJCLab-Orsay)

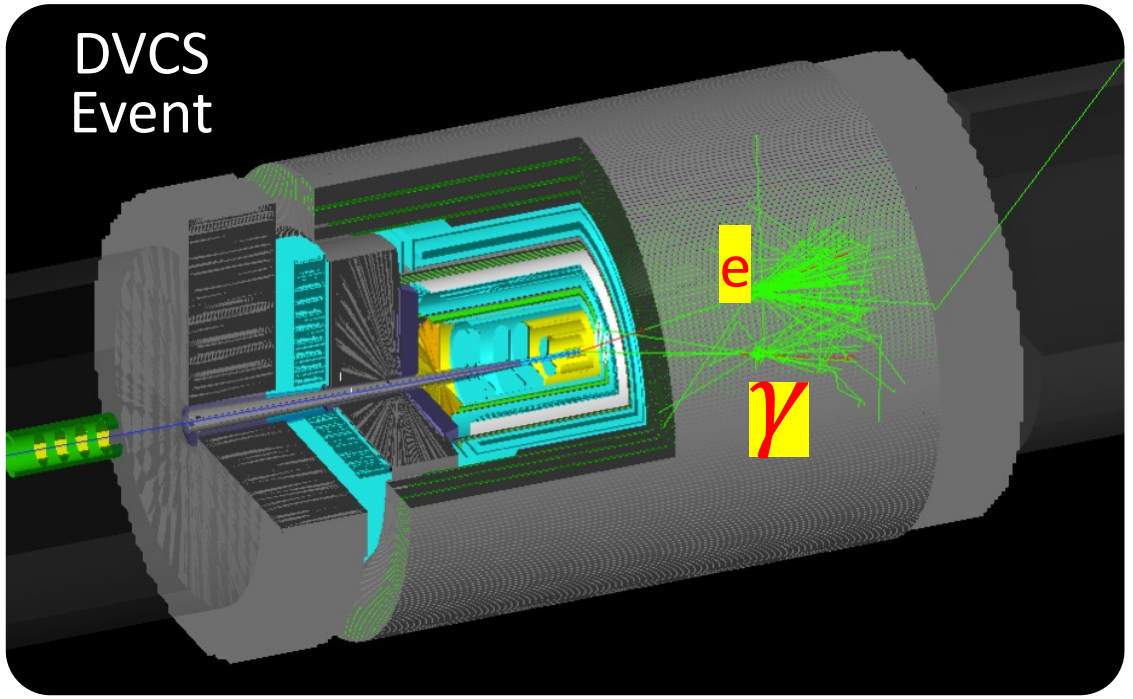
DIRC
- Re-use concept (CUA, GSI)
- Support structure (GSI)

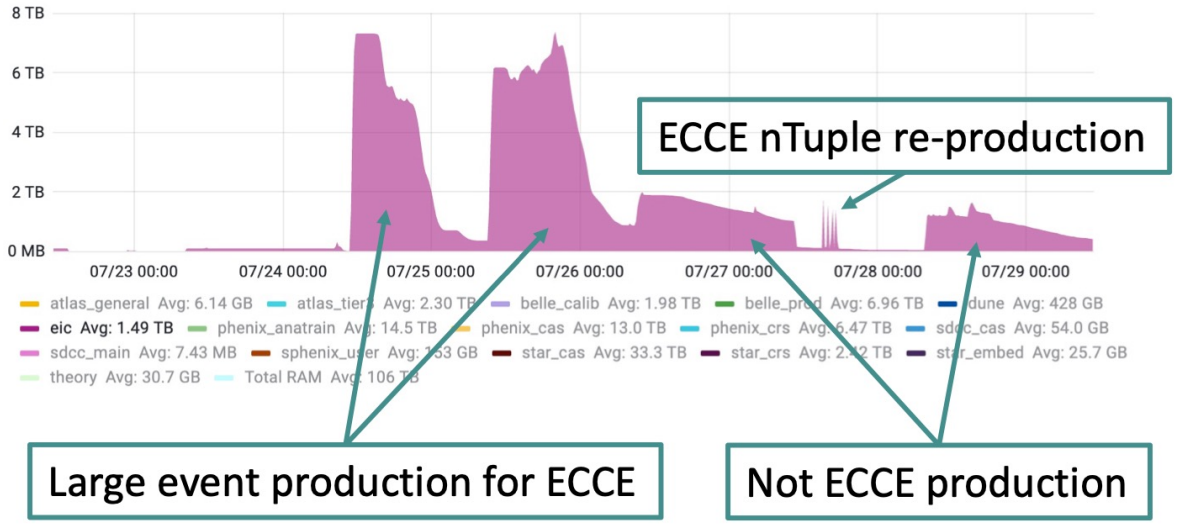


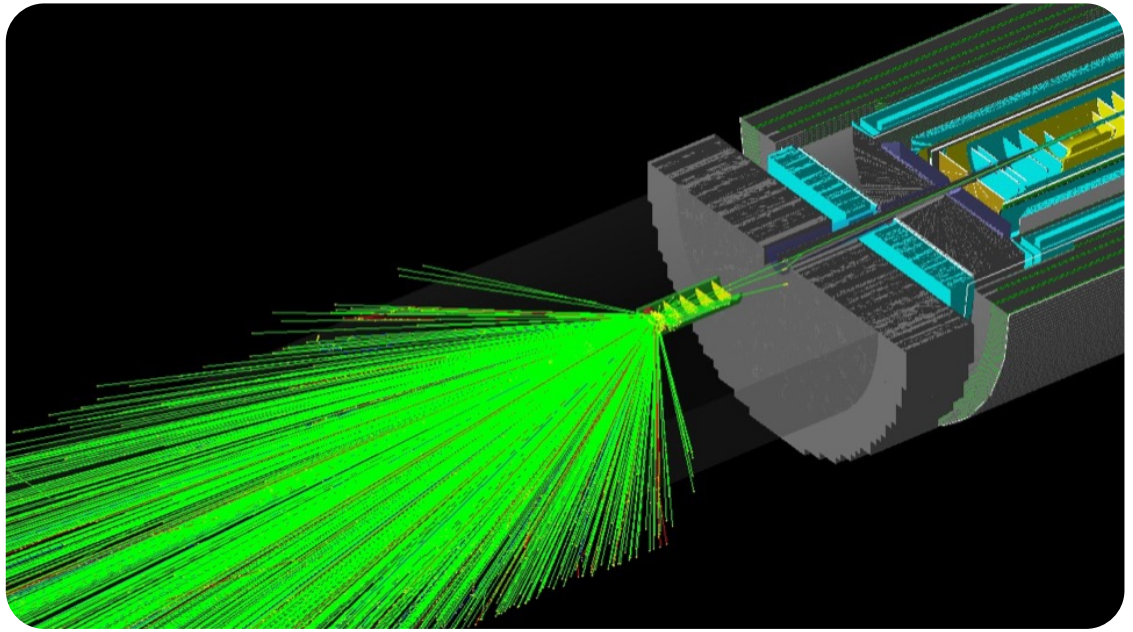
EIC Project :
- Barrel EMCal support & universal frame for DIRC, backward EMCAl, mRICH, etc.
- Forward Hadron Calorimeter, with maintenance model (looking at similar for the backward HCal)

ECCE Geant Simulations

- Full implementation in Fun4All.
- Setup running on BNL, JLab, BATES, OSG
- Completed 1st large-scale campaign (particle gun + physics generators)
- *150M events on tape!*







So… Can we do it with 1.5T?

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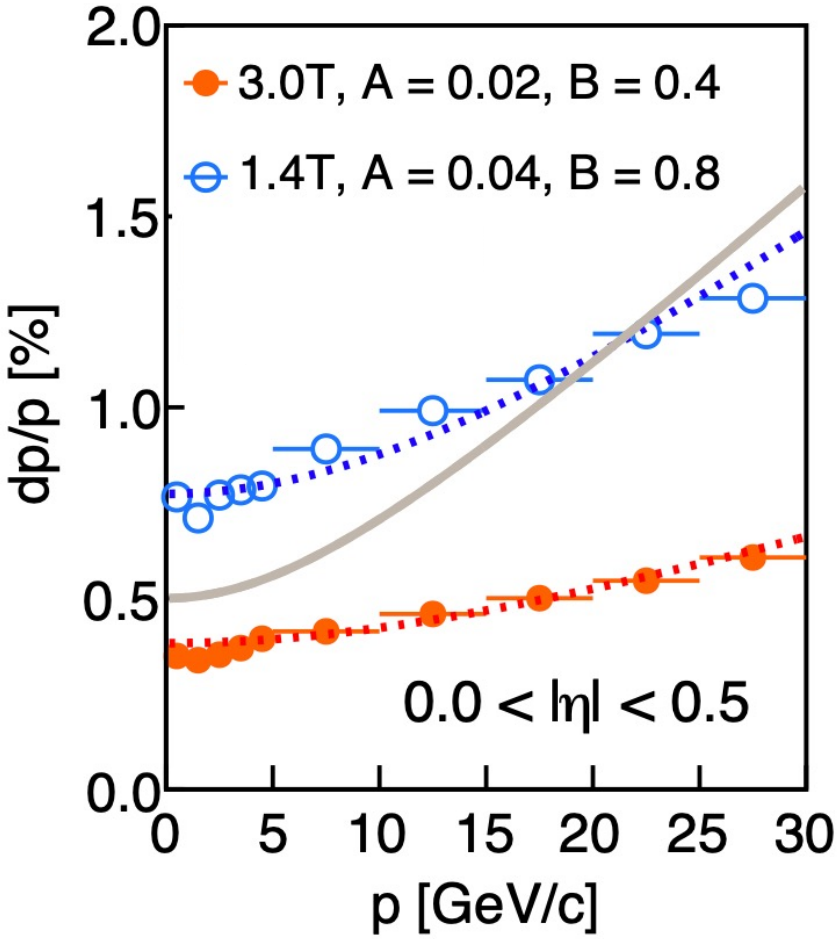
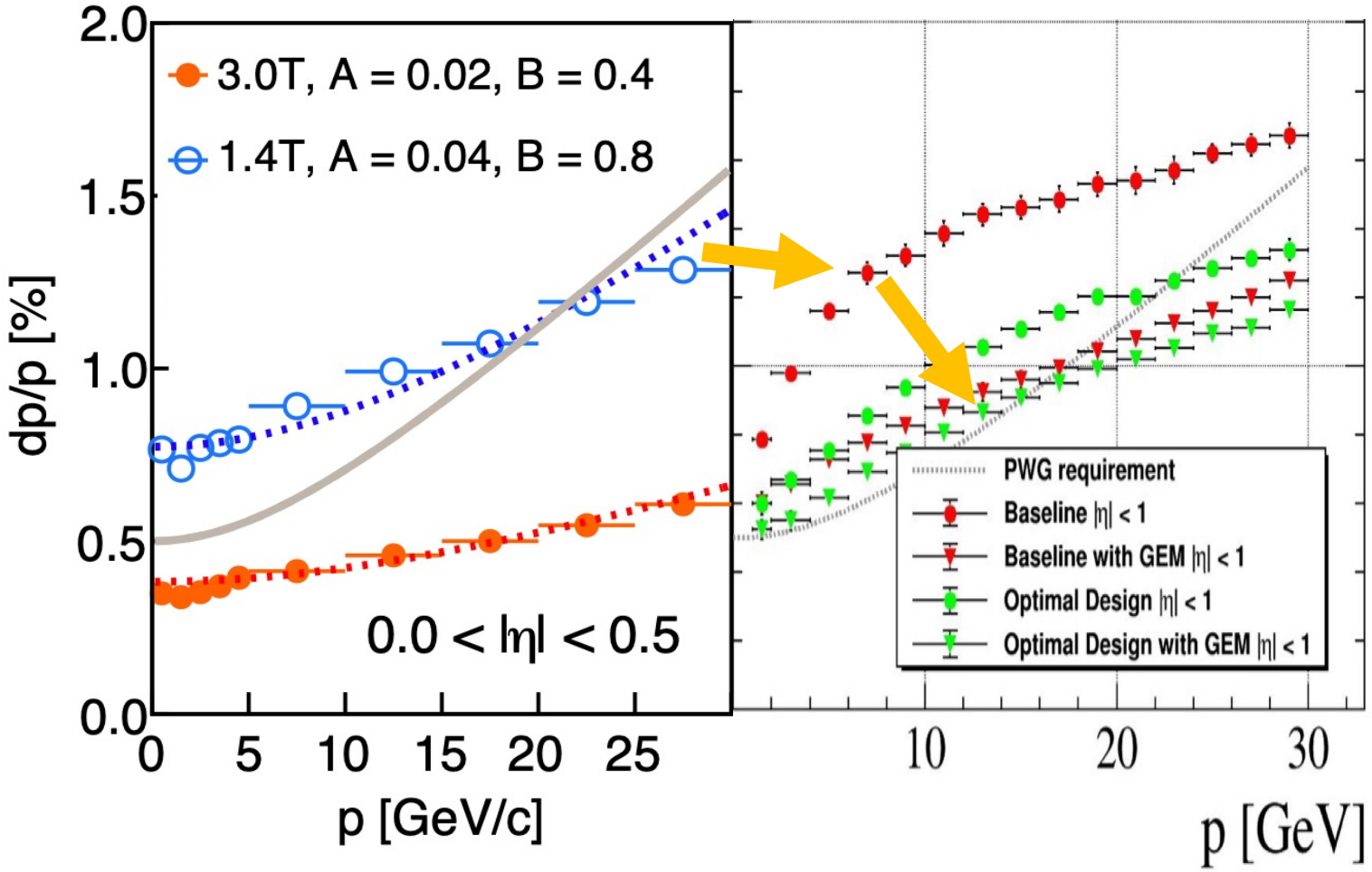
YR was a great start...



So… Can we do it with 1.5T?

YR was a great start… many developments since



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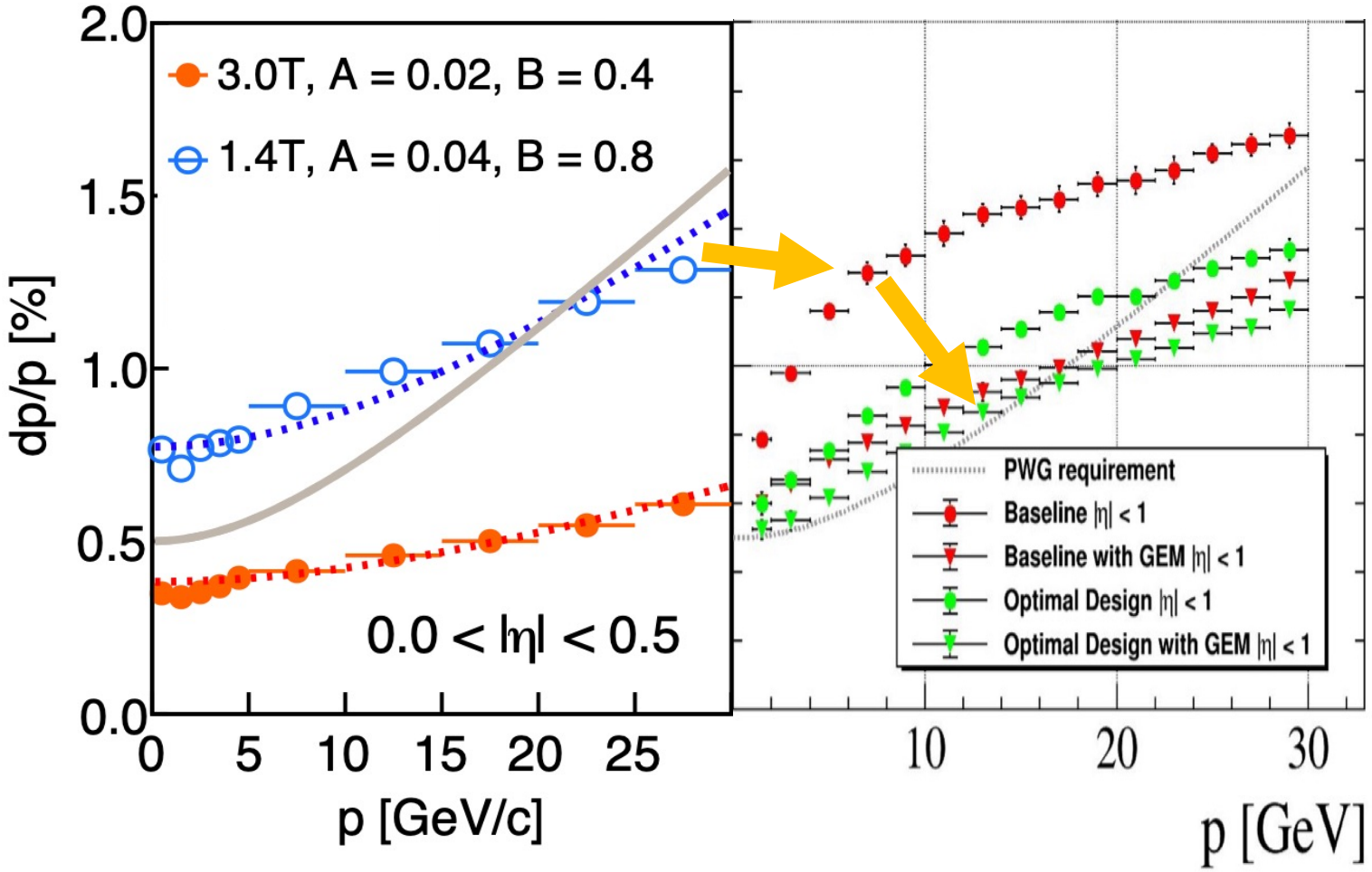


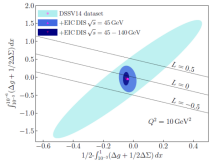
Getting close to YR specs

Able to deliver on NAS science!

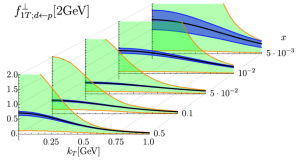
ECCE Physics Studies

Studies to demonstrate EIC NAS Study, Yellow Report physics

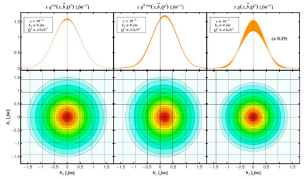
- Origin of Nucleon Spin



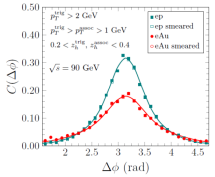
- Confined motion of partons



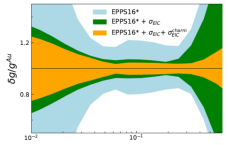
- 3D imaging of quarks and gluons



- Nucleon mass
- High gluon densities in nuclei

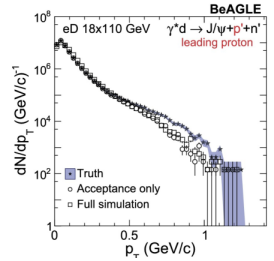


- Quarks and gluons in the nucleus

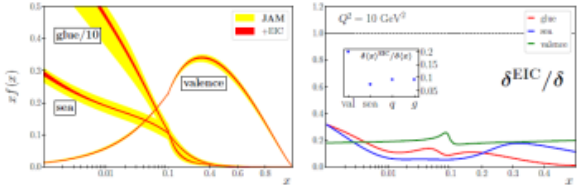


Studies to show unique ECCE strengths

- Light-ion tagging

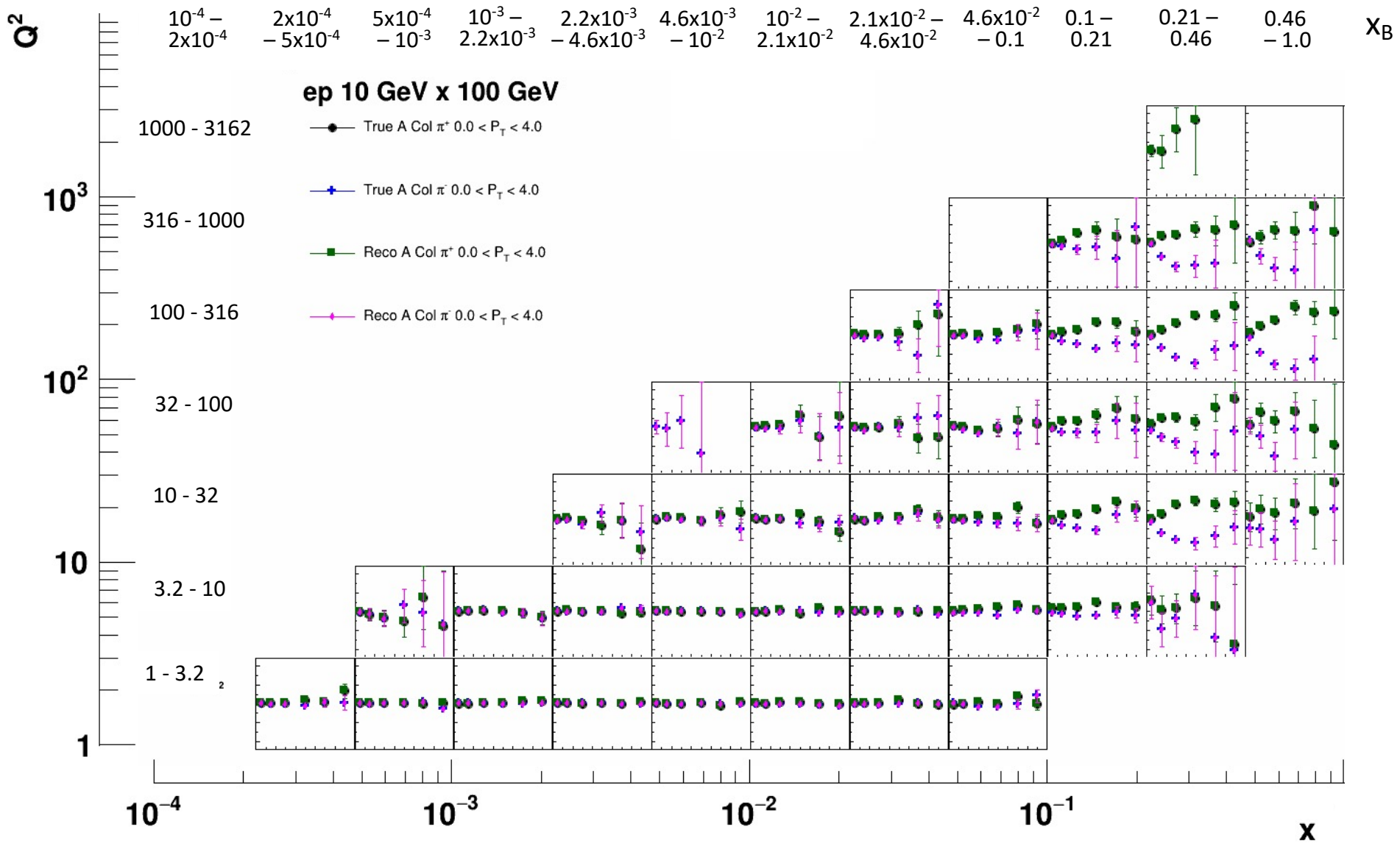


- Pion/Kaon structure

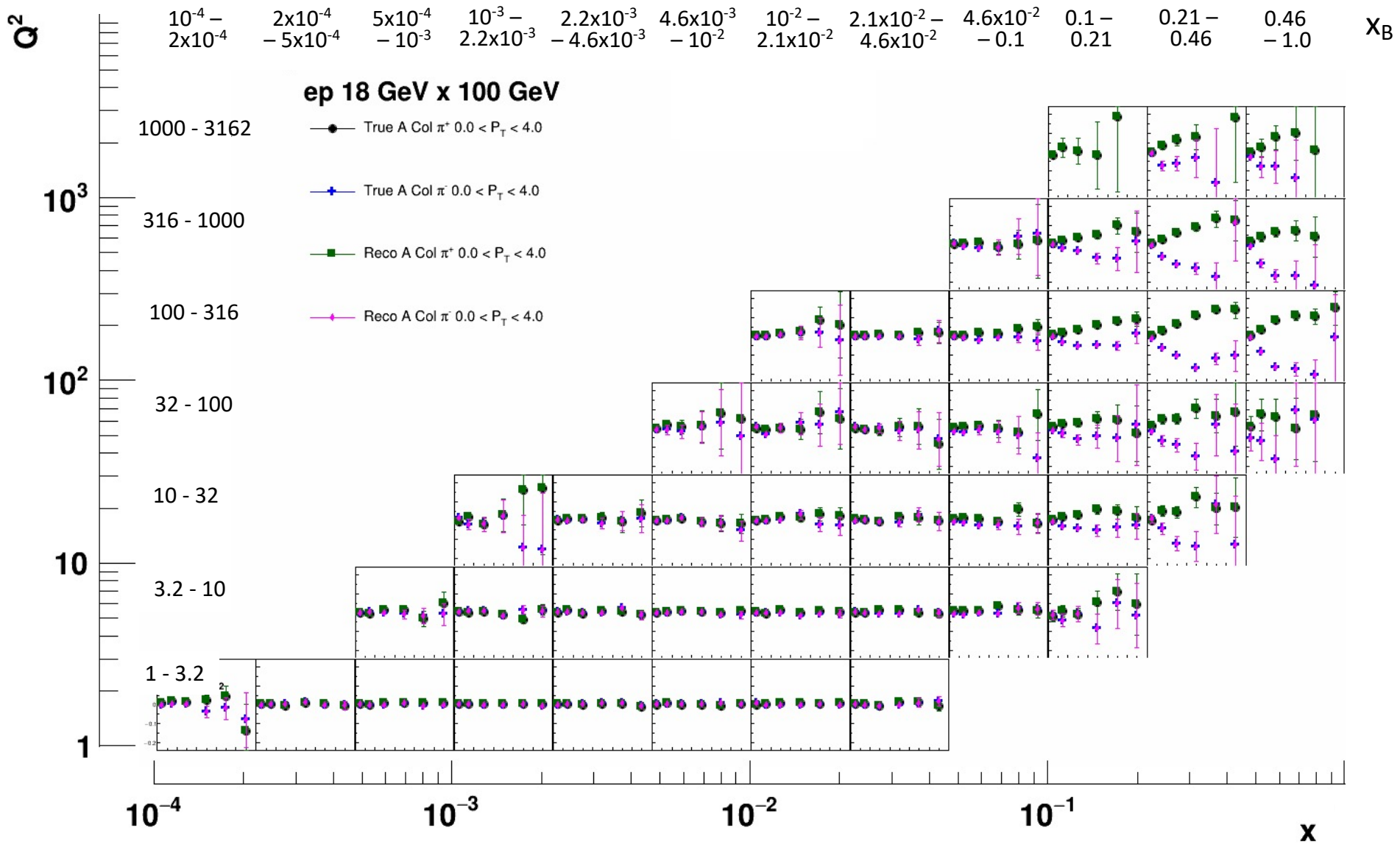


- Diffractive jets?
- Nuclear modifications and in-medium evolution
  - D/D* reconstruction and heavy-flavor in jets.

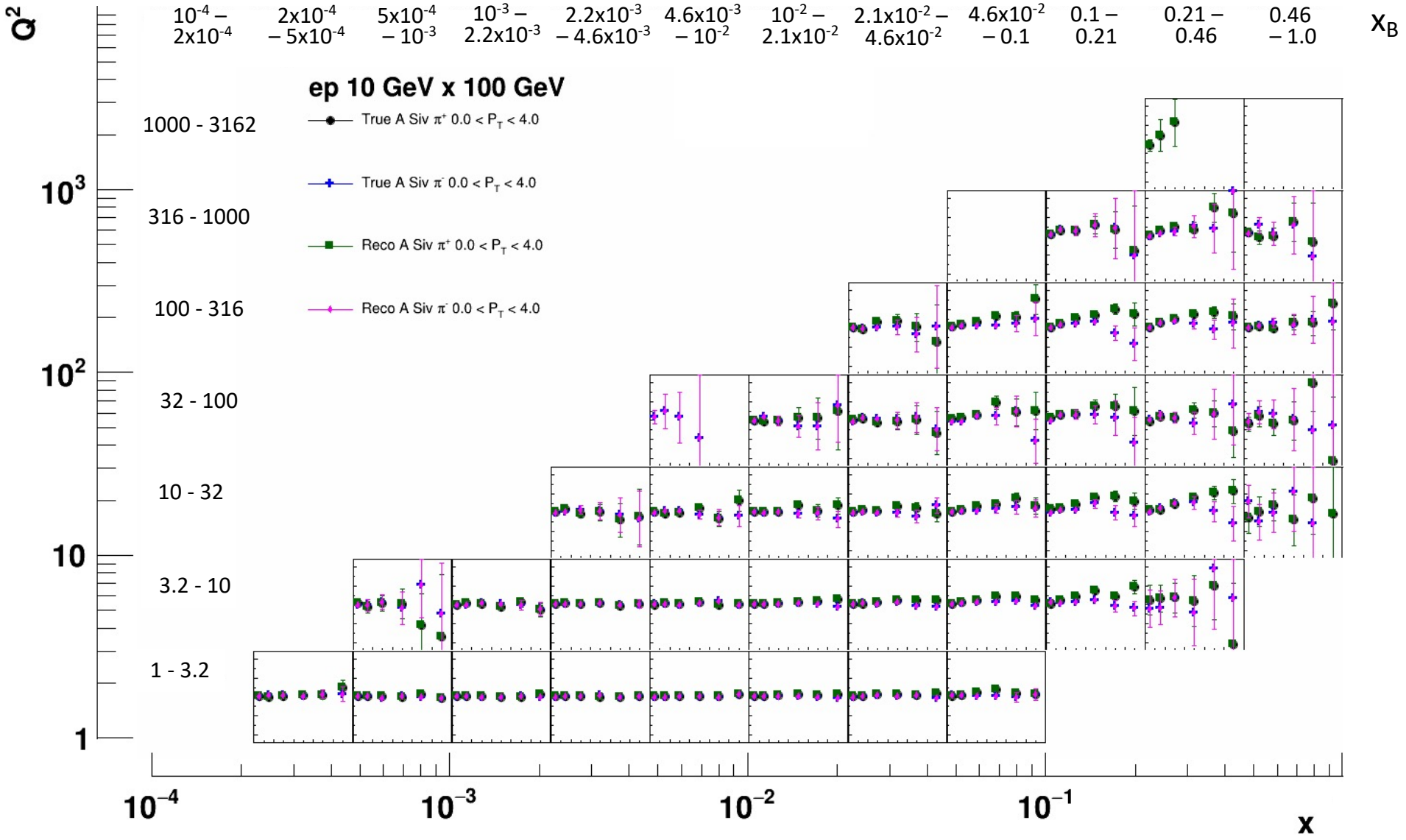
SIDIS Collins Asymmetries



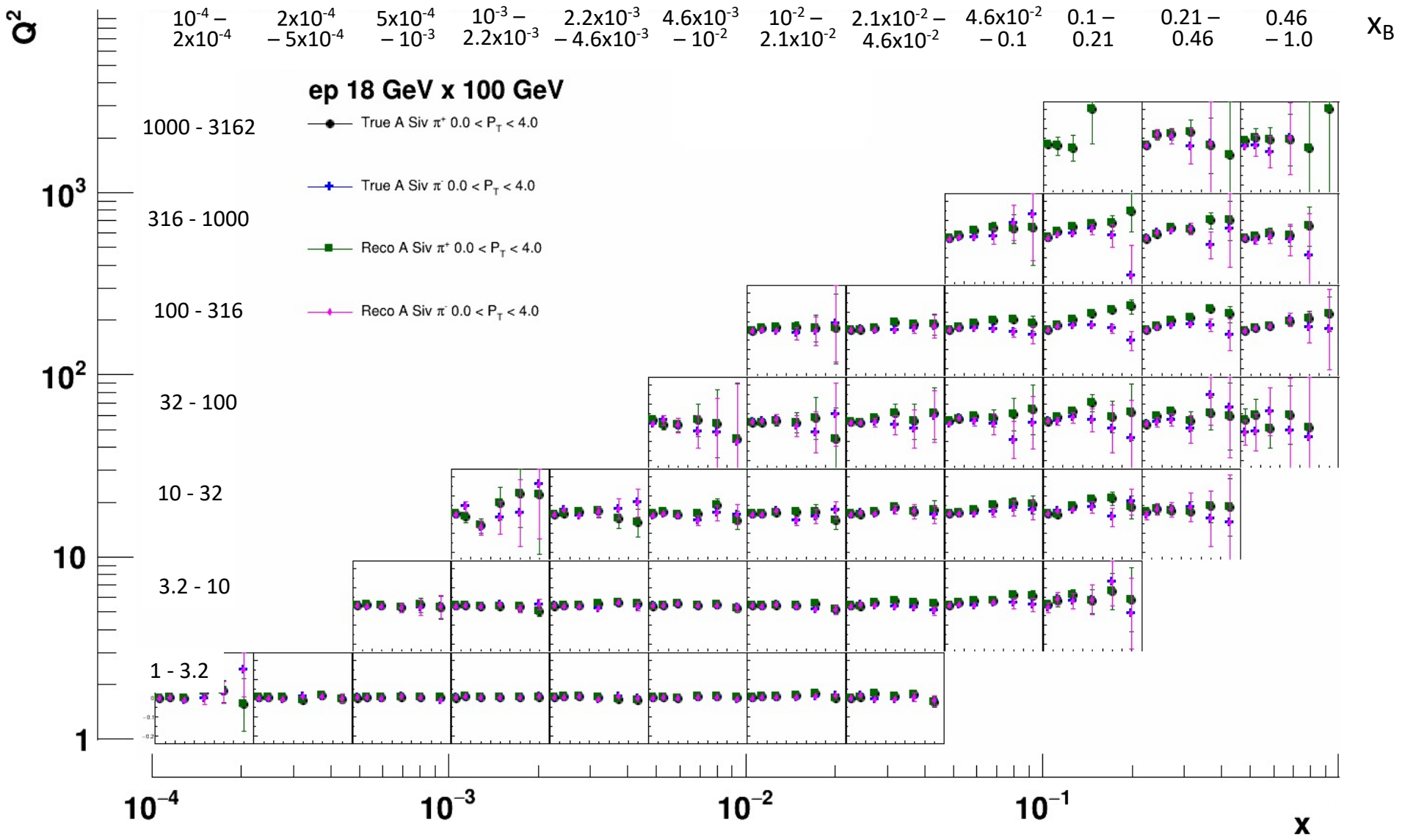
SIDIS Collins Asymmetries



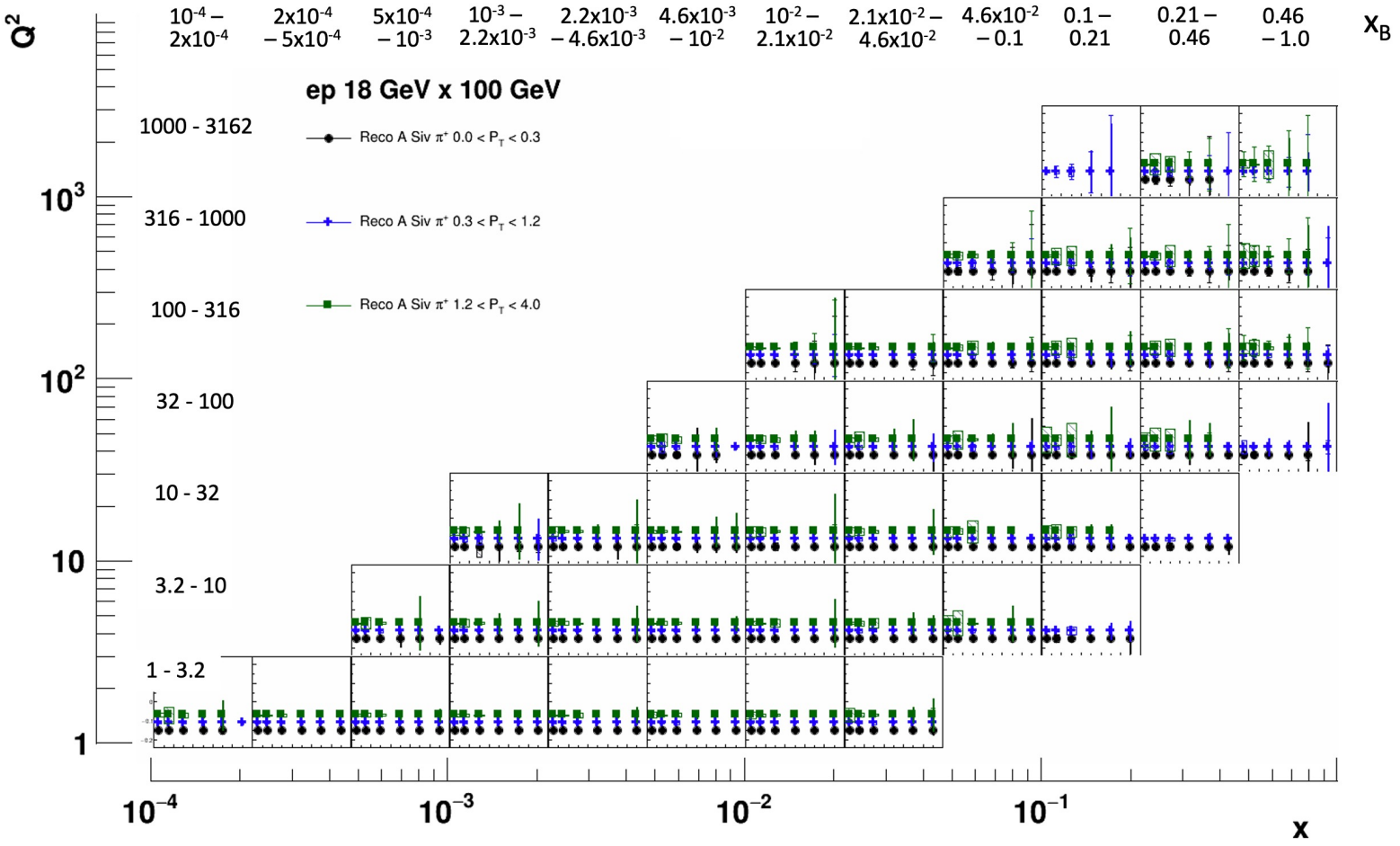
SIDIS Sivers Asymmetries

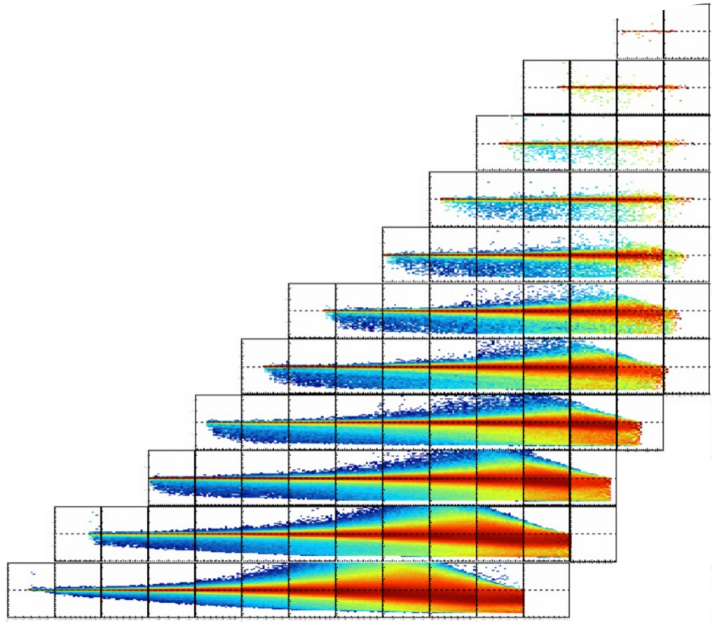


SIDIS Sivers Asymmetries



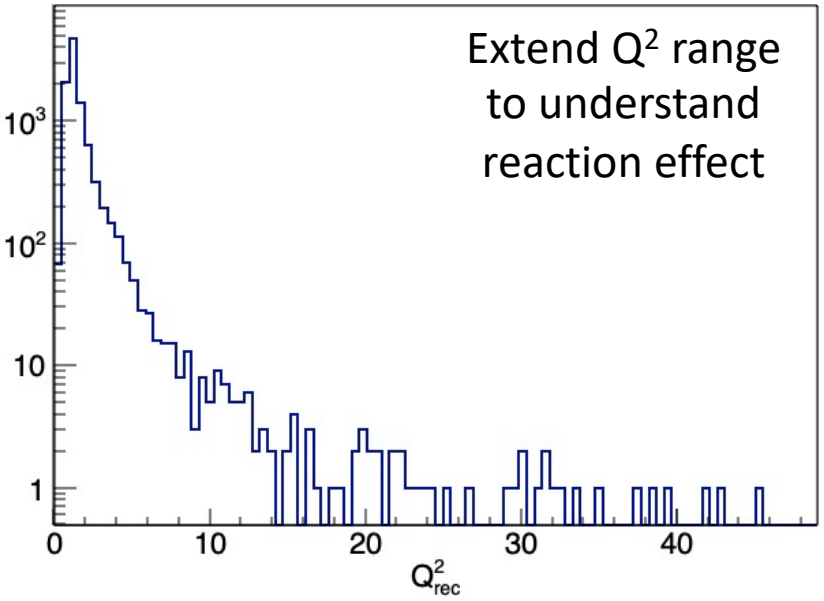
Uncertainties: 10 fb^{-1} statistics + systematics from reco-true deviation

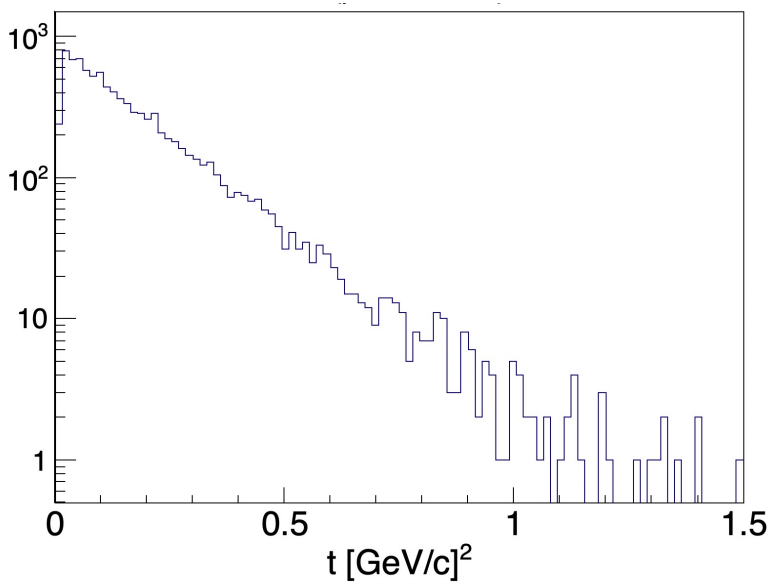


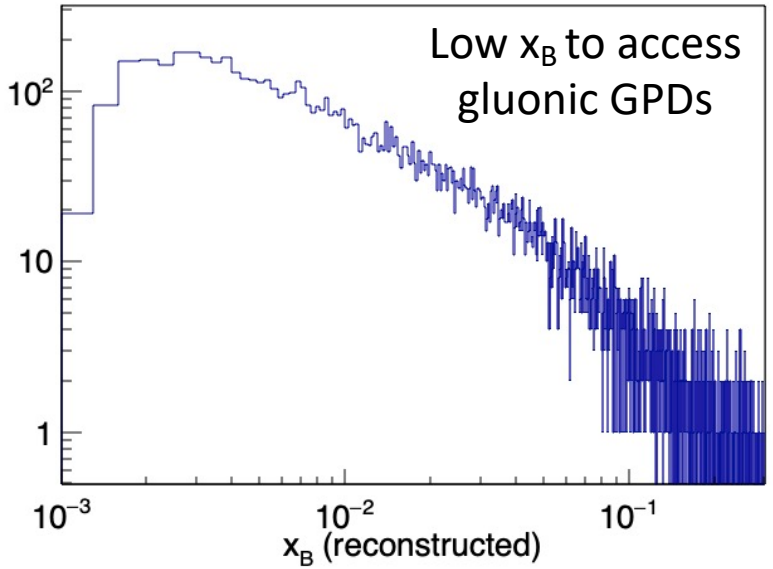


DVCS: ep → e'p'γ

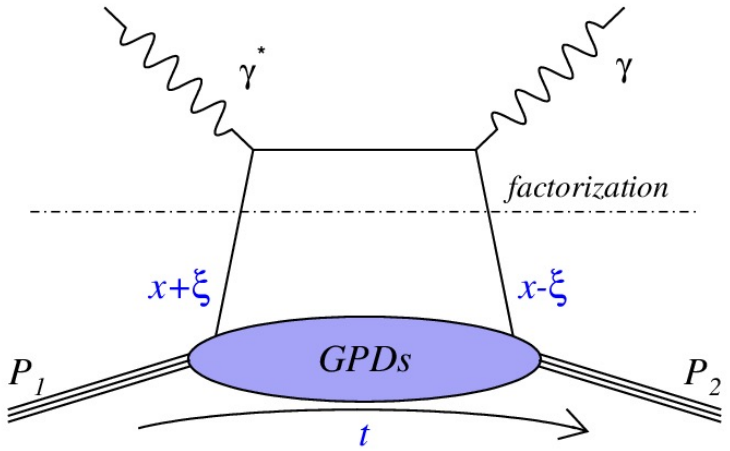
(5 x 41 GeV)







Understand Acceptance, Map Coverage



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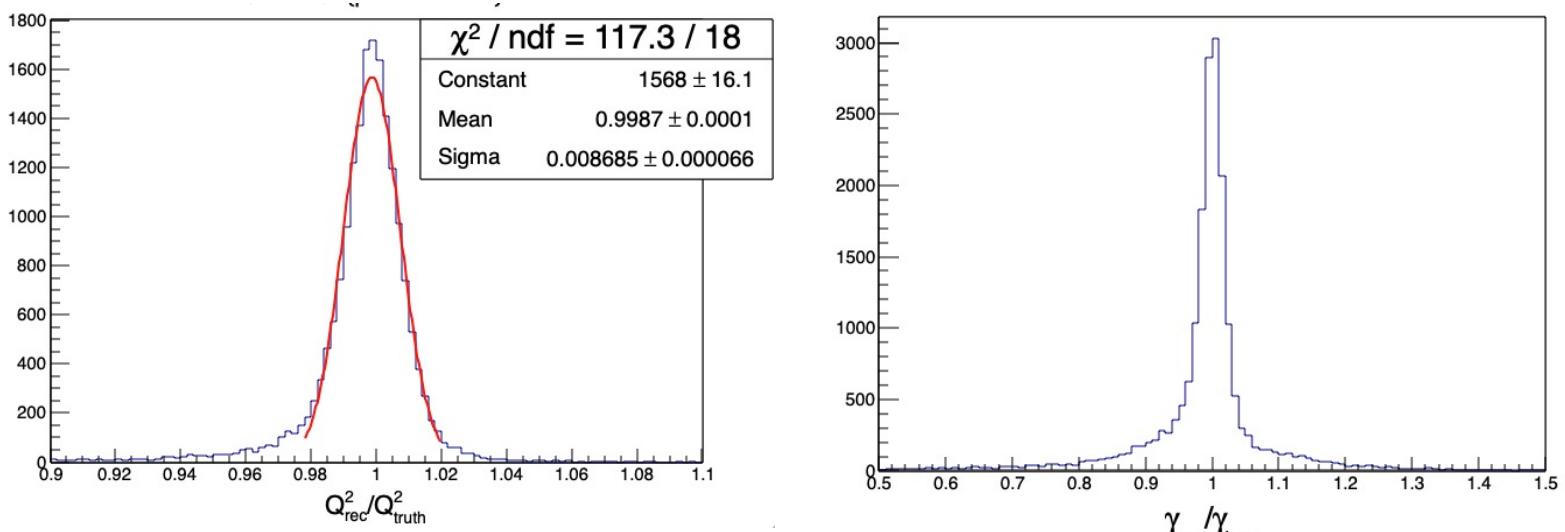
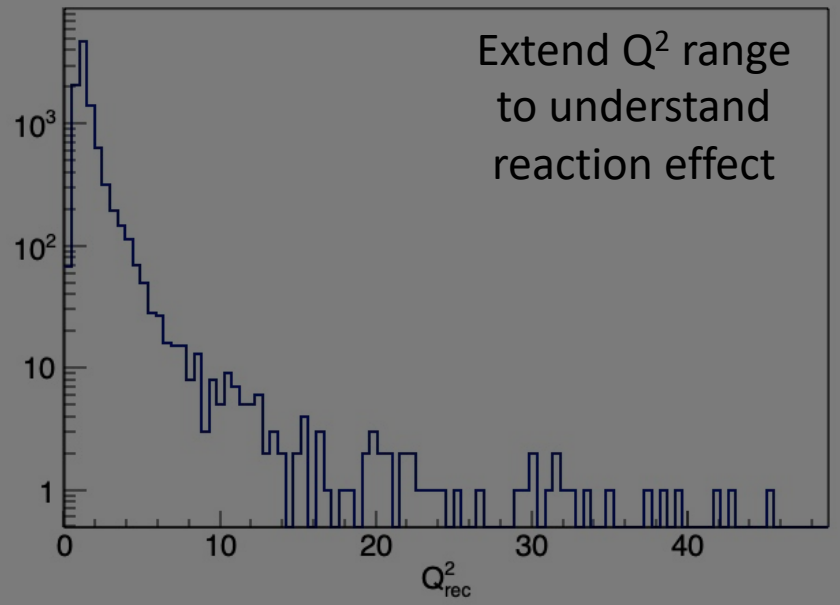
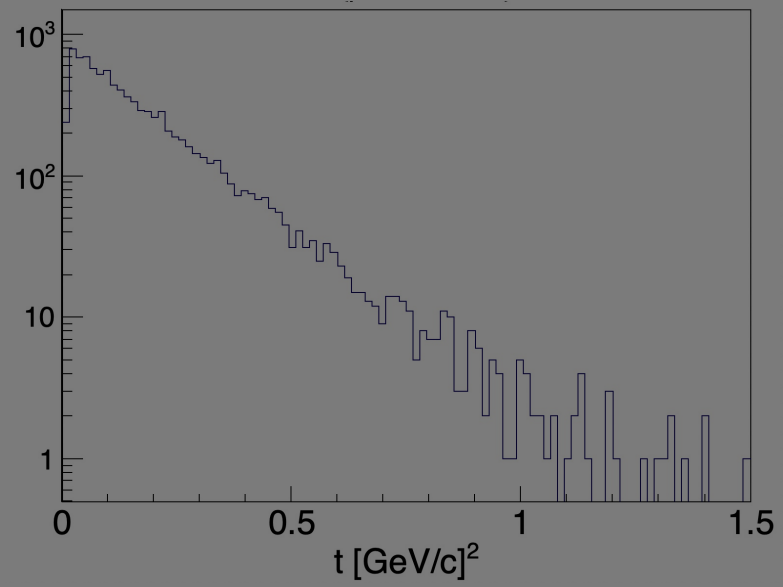
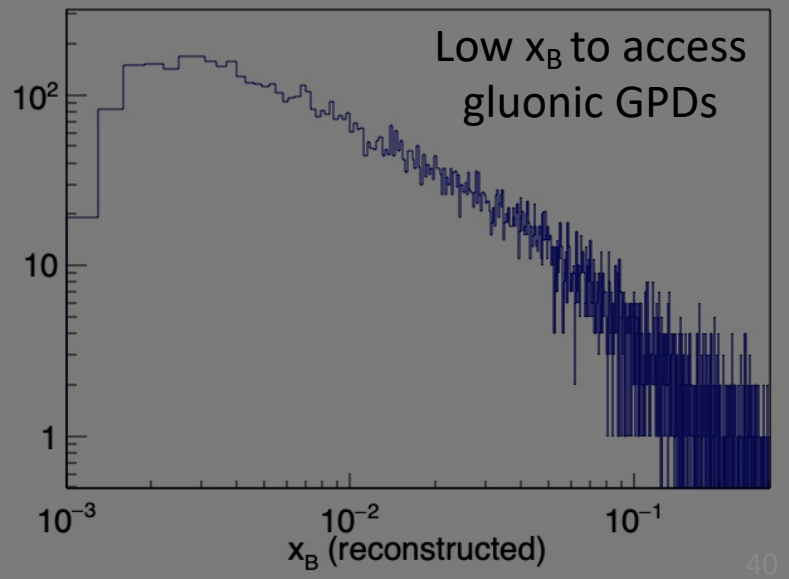


Reconstruction studies

(5 x 41 GeV)

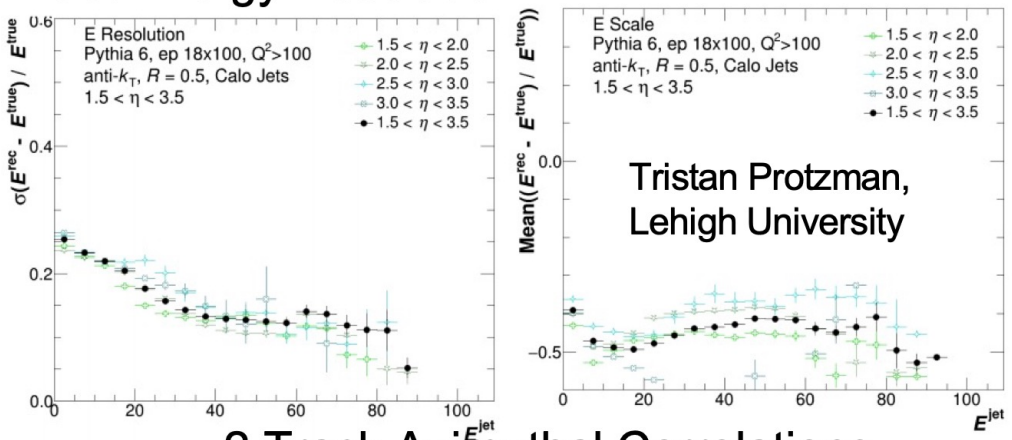






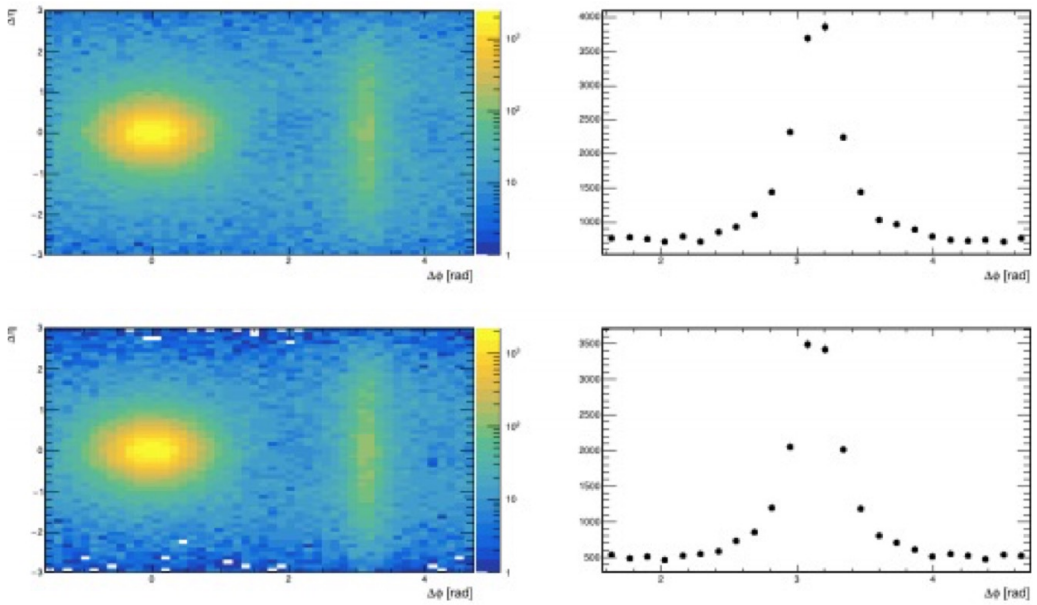
Jet Studies

Jet Energy Resolution



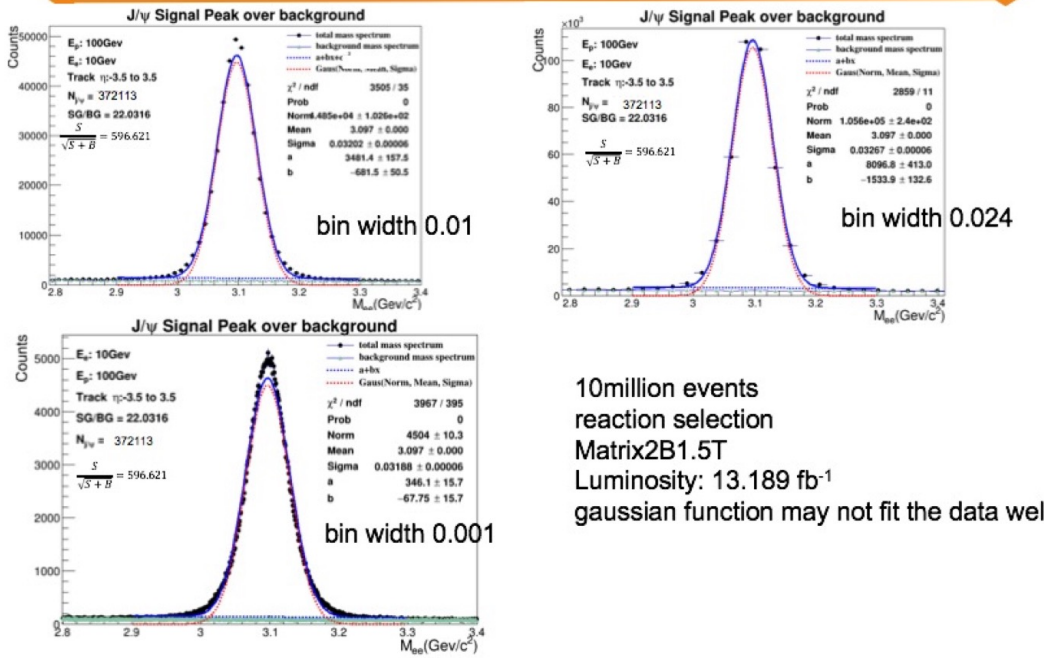
Tristan Protzman,
Lehigh University

2 Track Azimuthal Correlations



J/psi Reconstruction from First Simulation with Smearing

10 million events J/ψ peak(event filter)



10million events
reaction selection
Matrix2B1.5T
Luminosity: 13.189 fb^{-1}
gaussian function may not fit the data well.

Future Highlights

- ❑ July 1st - Aug. 1st [1 month]:
  - 1st Large scale simulations production DONE ☺
- ❑ Aug. 1st - Sep. 15th [1.5 months]:
  - Analysis of simulation data to demonstrate physics performance.
  - 2nd Large scale simulations production
- ❑ Sep. 15th - Nov. 1st [1.5 months]:
  - All physics ‘plots’ are done.
  - Final evaluation of technology selection based on physics studies results.
  - Proposal narrative composition around simulation results & selected technologies.
- ❑ Nov. 1st - Nov. 30th [1 month]:
  - Proposal review by external colleagues.
  - Final edits

Conclusions

- The ECCE consortium consists of 80 institutions working to design the EIC project detector based around the BaBar solenoid
- ECCE plans to be ready for physics by EIC CD4a for start of machine operations.
- The physics program spans the entirety of that outlined in the NAS study and the Yellow Report
- The detector design process is fully underway, in tandem with a wide range of full physics simulations.
- MANY ways to get involved!

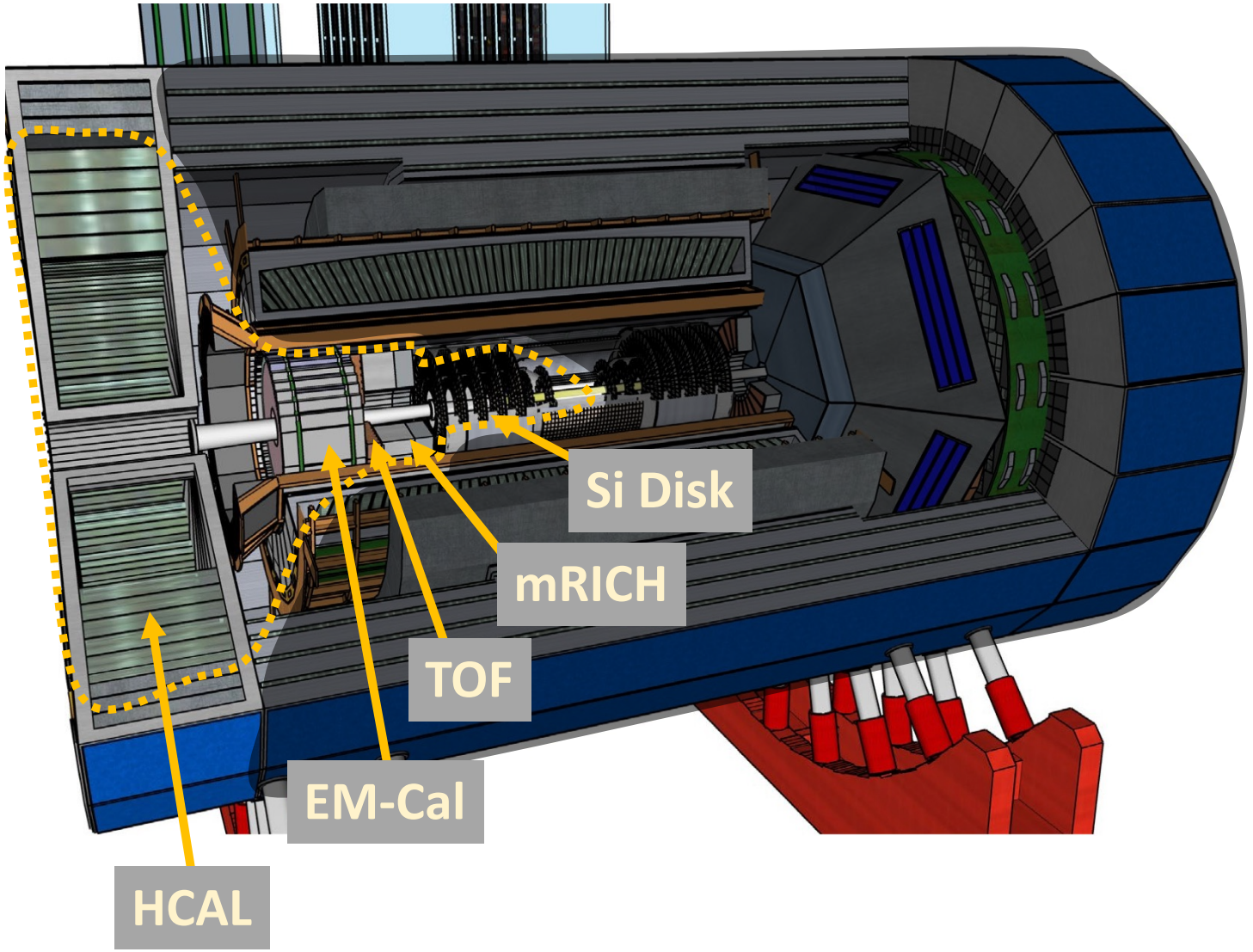
www.ecce-eic.org

Why ECCE ?

ECCE is a low-risk, cost-effective, flexible and optimized EIC detector!

- **Low risk** due to re-use of existing magnet and various detectors.
- **Cost-effective** due to magnet and detectors reuse.
- **Flexible and optimized** by studying both IRs and using full Geant4.
- **Most realistic detector to be ready by CD4a.**

ECCE Detector Layout



ELECTRON ENDCAP

Tracking: Large area μRWELL
Electron Detection:
- Inner: PbWO4 crystals (reuse some)
- Outer: SciGlass (backup PbGl)

h-PID: mRICH & AC-LGAD
HCAL: Fe/Sc (STAR re-use)

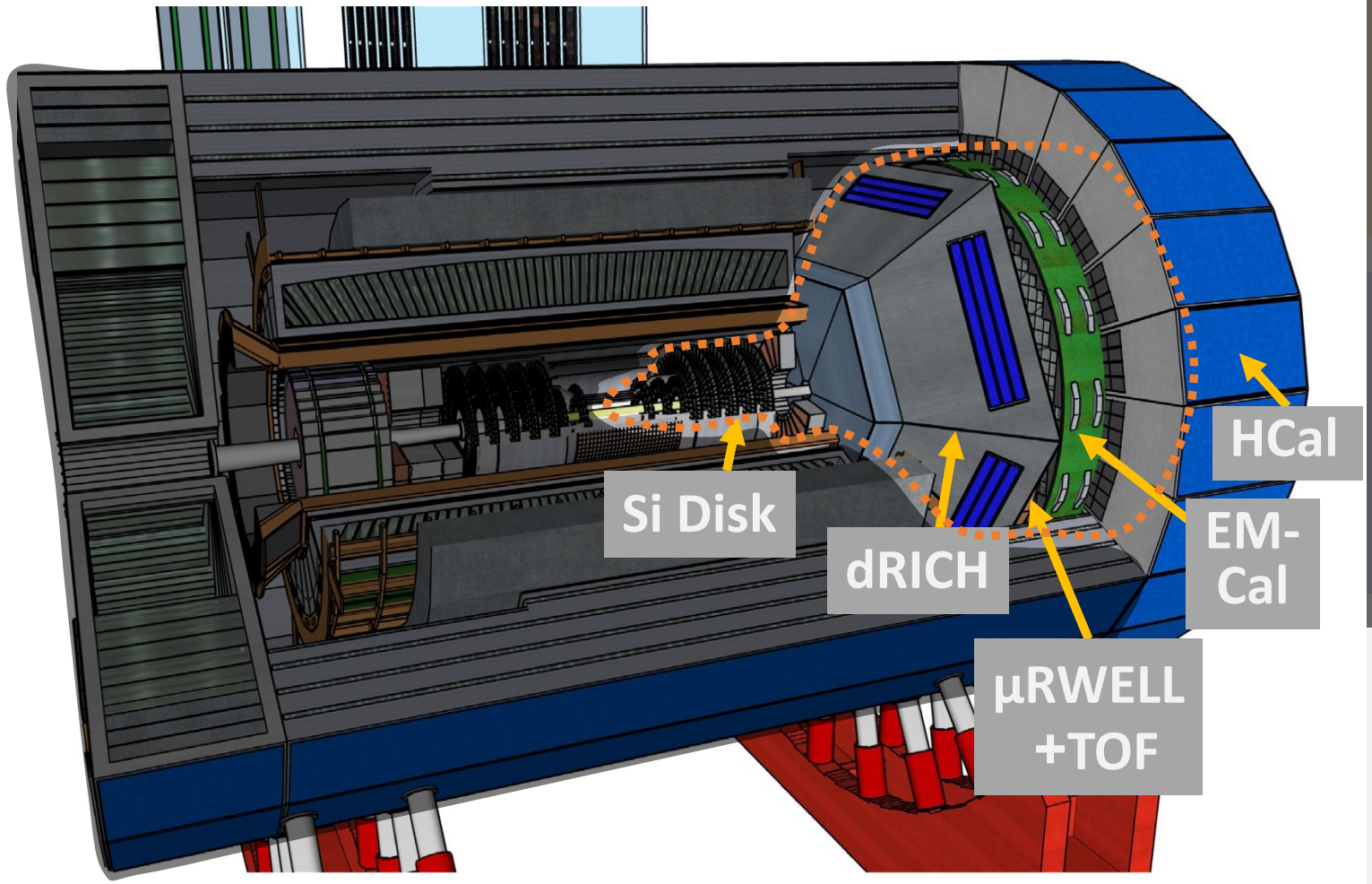
CENTRAL BARREL

Tracking: MAPS Si for vertexing and endcaps
(design to be optimized)
Electron PID: SciGlass (alt: PbGl or W(Pb)/Sc shashlik)
(plus instrumented frame)
h-PID: hpDIRC & AC-LGAD
HCAL: Fe/Sc (sPHENIX re-use)

HADRON ENDCAP

Tracking: Large area μRWELL
PID: dual-RICH & AC-LGAD
Calorimetry: (option A)
standard Pb/ScFi shashlik (PHENIX re-use)
long. sep. HCAL
(other options under study)

ECCE Detector Layout



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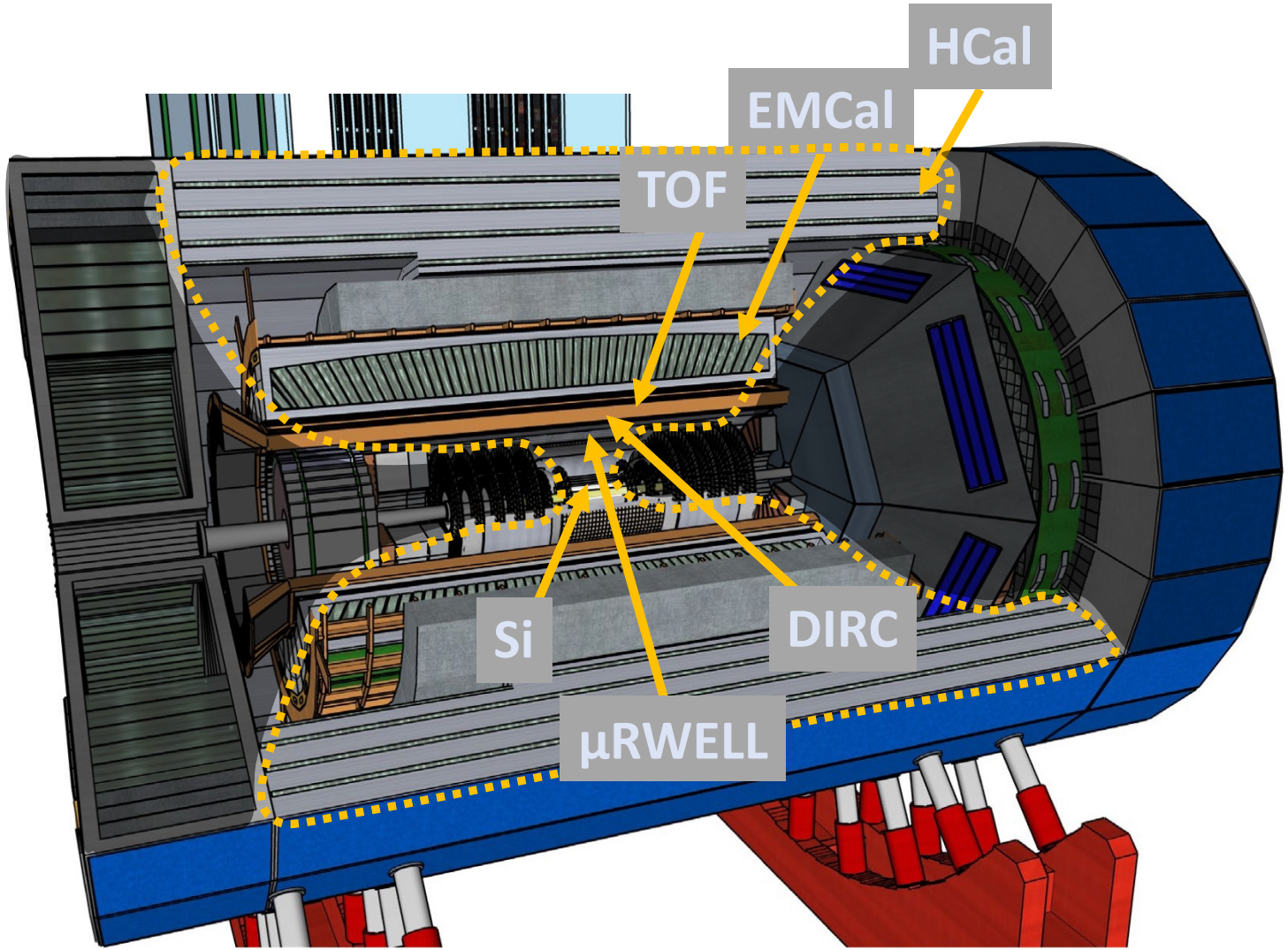

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